U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

3.8.4 OTHER SEISMIC CATEGORY I STRUCTURES

REVIEW RESPONSIBILITIES

Primary - ~~Structural Engineering Branch (SEB)~~ Civil Engineering and Geosciences Branch (ECGB)[1]

Secondary - None

I. AREAS OF REVIEW

The following areas relating to all seismic Category I structures and other safety-related structures that may not be classified as seismic Category I, other than the containment and its interior structures, are reviewed:

1. Description of the Structures

   The descriptive information, including plans and sections of each structure, is reviewed to establish that sufficient information is provided to define the primary structural aspects and elements relied upon for the structure to perform the safety-related function. Also reviewed is the relationship between adjacent structures, including the separation provided or structural ties, if any. Among the major plant structures that are reviewed, together with the descriptive information reviewed for each, are the following:

   a. Containment Enclosure Building

      The containment enclosure building, which may surround all or part of the primary concrete or steel containment structure, is primarily intended to reduce leakage during and after a loss-of-coolant accident (LOCA).~~ from within the~~

~~containment.~~[2] Concrete enclosure buildings also protect the primary containment, which may be of steel or concrete, from outside hazards.

The enclosure building is usually either a concrete structure or a structural-steel-and-metal-siding building.

Where it is a concrete structure, it usually has the geometry of the containment and, as applicable, the descriptive information reviewed is similar to that of a concrete containment as contained in subsection I.1 of Standard Review Plan (SRP)[3] Section 3.8.1.

Where it is a structural-steel-and-metal-siding building, the following items are reviewed: general arrangement of the building, including its foundations, wall, and roof; any bracing and lateral ties provided for the stability of the building; the roof supports which may bear on the dome of the containment; and major corner and siding joint connections.

b. Auxiliary Building

The auxiliary building, which is usually adjacent to the containment and which may be shared by the two containments in two-unit plants, is usually of reinforced concrete and structural steel construction. The general arrangement of the structural walls, columns, floors, roof, and any removable sections is reviewed.

c. Fuel Storage Building

The fuel storage building, which may be independent or part of the auxiliary building, is also of reinforced concrete and structural steel. It houses the new fuel storage area and the spent fuel pool. In addition to the information reviewed for the auxiliary building, the general arrangement of the spent fuel pool is reviewed, including its foundations and walls.

d. Control Building

The control room is located in most plants within the auxiliary building. However, where it is located in a separate building, usually called the control building, the building is reviewed as a separate structure. To provide missile protection and shielding, this building is usually of reinforced concrete and the descriptive information reviewed is similar to that reviewed for the auxiliary building.

e. Diesel Generator Building

The emergency diesel generators are, in some plants, located within the auxiliary building. However, they may also be located in a separate building called the diesel generator building. Again, this is usually a reinforced concrete structure, and the descriptive information reviewed is similar to that reviewed for the auxiliary building.

f. Other Structures

In most plants, there are several miscellaneous seismic Category I structures and other structures that may be safety-related but, because of other design provision, may not be classified as seismic Category I. These structures are usually either of reinforced concrete or structural steel, or a combination thereof. The descriptive information reviewed for such structures is similar to that reviewed for the auxiliary building. Among such structures are pipe and electrical conduit tunnels, waste storage facilities, stacks, intake structures, pumping stations, and cooling towers.

~~Further, the reviewer may encounter special safety-related structures such as emergency cooling water tunnels, embankments, concrete dams, and water wells. Such structures are reviewed on a case-by-case basis. The descriptive information provided is reviewed to understand the structural behavior of these structures, specifically during seismic events and plant process conditions during which such structures are required to remain functional.~~

Further, the reviewer may encounter special structures that are not located in the immediate vicinity of the site. When the failure of any such structure could affect the safety of the plant, it should be designed to withstand the effects of a safe shutdown earthquake (SSE) and the surface faulting should be comparable to that of the nuclear plant itself. Examples of such structures include emergency cooling water tunnels, embankments, concrete dams, and water wells. These structures are reviewed on a case-by-case basis, and safety assessments should take into account the material underlying the structure and its location with respect to the site. The descriptive information provided is reviewed to ascertain the structural behavior of such structures, particularly with respect to seismic events and plant process conditions during which they are required to remain functional.[4]

g. Masonry Walls

These are walls, partitions, or radiation shields which are components of the structures listed above. They are constructed of concrete masonry units (CMU) bonded with mortar in single or multiple wythes and may be reinforced horizontally as well as vertically. The arrangement and configuration of these walls ~~is~~are[5] reviewed.

2. <u>Applicable Codes, Standards, and Specifications</u>

The information pertaining to design codes, standards, specifications, regulatory guides, and other industry standards that are applied in the design, fabrication, construction, testing, and surveillance of seismic Category I structures is reviewed.

3. Loads and Loading Combinations

Information pertaining to the applicable design loads and various load combinations thereof is reviewed. The loads normally applicable to seismic Category I structures include the following:

a. Those loads encountered during normal plant startup, operation, and shutdown, including dead loads, live loads, thermal loads due to operating temperature, and hydrostatic loads such as those in spent fuel pools.

b. Those loads to be sustained during severe environmental conditions, including those induced by the operating basis earthquake (OBE) and the design wind specified for the plant.

c. Those loads to be sustained during extreme environmental conditions, including those induced by the safe shutdown earthquake (SSE) and the design tornado specified for the plant.

d. Those loads to be sustained during abnormal plant conditions. Such abnormal plant conditions include the postulated rupture of high- energy piping. Loads induced by such an accident may include elevated temperatures and pressures within or across compartments, and possibly jet impingement and impact forces associated with such ruptures.

The various combinations of the above loads that are normally postulated and reviewed include normal operating loads, normal operating loads with severe environmental loads, normal operating loads with extreme environmental loads, normal operating loads with abnormal loads, normal operating loads with severe environmental and abnormal loads, and normal operating with extreme environmental and abnormal loads.

The loads and load combinations described above are generally applicable to all types of structures. However, other site-related loads might also be applicable. Such loads, which are not normally combined with abnormal loads, include those induced by floods, potential aircraft crashes, explosive hazards in proximity to the site, and projectiles and missiles generated from activities of nearby military installations.

4. Design and Analysis Procedures

The design and analysis procedures used for Category I structures are reviewed with emphasis on the extent of compliance with ~~the~~ ACI 349, ~~Code~~ "Code Requirements for Nuclear Safety-Related Structures," ~~(Ref.1)~~[6]*[7] for concrete structures; ~~and~~ with ~~the AISC~~ANSI/AISC N690-1984, "Specifications for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities,"[8] ~~Specifications (Ref. 3)~~[9] for

* Whenever reference is made to ACI 349, it implies that the code is augmented by Regulatory Guide 1.142, ~~(Ref. 2)~~ as supplemented by Appendix E to this SRP section.

steel structures; and supplemented by Appendices E, F, and G to this SRP section,[10] including the following areas:

a. General assumptions on boundary conditions.

b. The expected behavior under loads and the methods by which vertical and lateral loads and forces are transmitted from the various elements to their supports and eventually to the foundation of the structure.

c. The computer programs that are utilized.

d. A design report on Category I structures is reviewed (Appendix C).

e. A structural audit is performed (Appendix B).

f. The design of the spent fuel pool and racks is reviewed (Appendix D).

g. Steel embedments are reviewed (Appendix E).[11]

h. Steel-related structures are evaluated on the basis of ANSI/AISC N690-1984 (Appendix F).[12]

i. Dynamic soil pressures on earth retaining walls and embedded walls are reviewed for nuclear power plant structures (Appendix G).[13]

5. Structural Acceptance Criteria

The design limits imposed on the various parameters that serve to quantify the structural behavior of each structure and its components are reviewed, specifically with respect to stresses, strains, gross deformations, and factors of safety against structural failure. For each load combination specified, the~~ specified~~[14] allowable limits are compared with the acceptable limits delineated in subs~~S~~ection II.5 of this SRP section~~plan~~.[15]

6. Materials, Quality Control, Special Construction Techniques, and Quality Assurance

Information on the materials that are used in the construction of Category I structures is reviewed. Among the major materials of construction that are reviewed are the concrete ingredients, the reinforcing bars and splices, and the structural steel and anchors.

The quality control parameters that are proposed for the fabrication and construction of Category I structures are reviewed, including nondestructive examination of the materials to determine physical properties, placement of concrete, and erection tolerances.

Special construction techniques, if proposed, are reviewed on a case-by-case basis to determine their effects on the structural integrity of the completed structure.

In addition, the information contained in items a, b, and c of subsection I.6 of ~~Standard Review Plan~~SRP Section 3.8.3 is also reviewed.

7. Testing and Inservice Surveillance Programs

If applicable, any post-construction testing and inservice surveillance programs are reviewed on a case-by-case basis.

8. Masonry Walls

Areas of review pertaining to masonry walls should include, at a minimum, those items identified in Appendix A to this SRP section.

Review Interfaces[16]

~~SEB~~ECGB[17] coordinates other branches evaluations that interface with structural engineering aspects of the review as follows:

1.[18] Determination of structures which are subject to quality assurance programs in accordance with the requirements of Appendix B to 10 CFR Part 50 is performed by the Mechanical Engineering Branch ~~(MEB)~~(EMEB)[19] as part of its primary review responsibility for SRP Sections 3.2.1 and 3.2.2. ~~SEB~~The ECGB[20] will perform its review of safety-related structures on that basis.

2.[21] Determination of pressure loads from high-energy lines located in safety-related structures other than containment is performed by the ~~Auxiliary Systems Branch (ASB)~~ Plant Systems Branch (SPLB)[22] as described as part of its primary review responsibility for SRP Section 3.6.1. ~~SEB~~ The ECGB[23] accepts the loads thus generated as approved by the ~~ASB~~ SPLB.[24] to be included in the load combination equations of this SRP section.

3.[25] Determination of loads generated due to pressure under accident conditions is performed by the ~~Containment Systems Branch (CSB)~~Containment Systems and Severe Accident Branch (SCSB)[26] as part of its primary review responsibility for SRP Section 6.2.1. ~~SEB~~The ECGB[27] accepts the loads thus generated, as approved by the ~~CSB~~SCSB,[28] to be included in the load combinations in this SRP section.

4.[29] The review for quality assurance is coordinated and performed by the ~~Quality Assurance Branch~~Quality Assurance and Maintenance Branch (HQMB)[30] as part of its primary review responsibility for SRP ~~Section 17.0~~Chapter 17.[31]

5. The ECGB coordinates with the Materials and Chemical Engineering Branch (EMCB) regarding exclusion of postulated pipe ruptures from the design basis, generally referred to as the "leak before break (LBB)." The EMCB performs a review of those applications that propose to eliminate consideration of design loads associated with the dynamic effects of pipe rupture, as part of its primary review responsibility for SRP Section 3.6.3 (to be developed).[32]

For those areas of review identified above as ~~being reviewed as~~ part of the primary ~~review~~ responsibility of other branches, the acceptance criteria ~~necessary for the review~~ and ~~their~~ methods of application are contained in the referenced SRP sections ~~of the corresponding primary branch~~.[33]

II. ACCEPTANCE CRITERIA

~~SEB~~The ECGB[34] acceptance criteria for the design of structures other than containment are based on meeting the relevant requirements of the following regulations:

A. ~~Part 50 of~~ 10 CFR~~, §~~ 50.55a and General Design Criterion 1 (GDC 1)[35] as they relate to safety-related structures being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed.

B. General Design Criterion 2 (GDC 2)[36] as it relates to the design of the safety-related structures being capable to withstand the most severe natural phenomena such as wind, tornadoes, floods, and earthquakes and the appropriate combination of all loads.

C. General Design Criterion 4 (GDC 4)[37] as it relates to safety-related structure being capable of withstanding the dynamic effects of equipment failures including missiles and blowdown loads associated with the loss of coolant accidents.

D. General Design Criterion 5 (GDC 5)[38] as it relates to sharing of structures important to safety, unless it can be shown that such sharing will not significantly impair their validity to perform their safety functions.

E. Appendix B to 10 CFR Part 50 as it relates to the quality assurance criteria for nuclear power plants.

The regulatory guides and industry standards identified in item 2 of this subsection provide~~s~~ information, recommendations, and guidance and in general describes a basis acceptable to the staff that may be used to implement the requirements of 10 CFR 50.55a and ~~GDC~~General Design Criteria 1, 2, 4, and[39] 5 and Appendix B to 10 CFR Part 50. Also, specific acceptance criteria necessary to meet the relevant requirements of these regulations for the areas of review, described in subsection I of this SRP section, are as follows:

1. Description of the Structures

The descriptive information in the safety analysis report (SAR) is considered acceptable if it meets the minimum requirements set forth in Section 3.8.4.1 of the "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," Regulatory Guide (RG) 1.70.

Deficient areas of descriptive information are identified by the reviewer and a request for additional information is initiated at the application acceptance review. New or unique design features that are not specifically covered in ~~the "Standard Format...",~~ RG 1.70[40] may require a more detailed review. The reviewer determines the additional information that may be required to accomplish a meaningful review of the structural aspects of such new or unique features.

2. Applicable Codes, Standards, and Specifications

The design, materials, fabrication, erection, inspection, testing, and surveillance, if any, of Category I structures are covered by codes, standards, and guides that are either applicable in their entirety or in portions thereof. A list of such documents is as follows:

Specifications	Title
ACI 349	Code Requirements for Nuclear Safety-Related Concrete Structures (supplemented by Appendix E to this SRP section and RG 1.142)[41]
ANSI/AISC N690-1984	~~Specification for the Design, Fabrication and Erection of Structural Steel for Buildings~~Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities[42]

Regulatory Guides

~~1.10~~	~~Mechanical (Cadweld) Splices in Reinforcing Bars of Category I Concrete Structures~~
~~1.15~~	~~Testing of Reinforcing Bars for Category I Concrete Structures~~
~~1.55~~	~~Concrete Placement in Category I Structures~~[43]
1.69	Concrete Radiation Shields for Nuclear Power Plants
1.91	Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants
1.94	Quality Assurance Requirements for Installation, Inspection, and Testing of Structural Concrete
1.115	Protection Against Low Trajectory Turbine Missiles
1.142	Safety-Related Concrete Structures for Nuclear Power Plants (Other Than Reactor Vessels and Containments)
1.143	Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in LWR Plants

3. Loads and Load Combinations

The specified loads and load combinations are acceptable if found to be in accordance with the following:

a. Loads, Definitions, and Nomenclature

All major loads to be encountered or to be postulated are listed below. All loads listed, however, are not necessarily applicable to all the structures and their elements. Loads and the applicable load combinations for which each structure has to be designed will depend on the conditions to which that particular structure may be subjected.

Normal loads, which are those loads to be encountered during normal plant operation and shutdown, include:

D - Dead loads or their related internal moments and forces, including any permanent equipment loads.

L - Live loads or their related internal moments and forces, including any movable equipment loads and other loads which vary with intensity and occurrence, such as soil pressure. The dynamic effects of lateral soil pressure should be accounted for in accordance with the provisions of Appendix G to this SRP section.[44]

T_0 - Thermal effects and loads during normal operating or shutdown conditions, based on the most critical transient or steady state condition.

R_0 - Pipe reactions during normal operating or shutdown conditions, based on the most critical transient or steady state condition.

Severe environmental loads include:

E - Loads generated by the operating basis earthquake.

W - Loads generated by the design wind specified for the plant.

Extreme environmental loads include:

E' - Loads generated by the ~~safe shutdown earthquake~~SSE.[45]

W_t - Loads generated by the design tornado specified for the plant. Tornado loads include loads due to the tornado wind pressure, the tornado-created differential pressure, and tornado-generated missiles.

Abnormal loads, which are those loads generated by a postulated high-energy pipe break accident, include:

P_a - Pressure equivalent static load within or across a compartment generated by the postulated break, including an appropriate dynamic load factor to account for the dynamic nature of the load.

T_a - Thermal loads under thermal conditions generated by the postulated break, including T_0.

R_a - Pipe reactions under thermal conditions generated by the postulated break, including R_0.

Y_r - Equivalent static load on the structure generated by the reaction on the broken high-energy pipe during the postulated break, including an appropriate dynamic load factor to account for the dynamic nature of the load.

Y_j - Jet impingement equivalent static load on a structure generated by the postulated break, including an appropriate dynamic load factor to account for the dynamic nature of the load.

Y_m - Missile impact equivalent static load on a structure generated by or during the postulated break, as from pipe whipping, including an appropriate dynamic load factor to account for the dynamic nature of the load.

In determining an appropriate equivalent static load for Y_r, Y_j, and Y_m, elasto-plastic behavior may be assumed with appropriate ductility ratios, provided excessive deflections will not result in loss of function of any safety-related system.

b. Load Combinations for Concrete Structures

For concrete structures, the load combinations are acceptable if found in accordance with the following:

(i) For service load conditions, either the working stress design (WSD) method, as outlined in the ACI 318 Code, or the strength design method may be used.

(a) If the WSD method is used, the following load combinations should be considered:

(1) D + L

(2) D + L + E

(3) D + L + W

If thermal stresses due to T_0 and R_0 are present, the following combinations should also be considered:

(4) $D + L + T_0 + R_0$

(5) $D + L + T_0 + R_0 + E$

(6) $D + L + T_0 + R_0 + W$

~~Both c~~Cases ~~of~~in which L ~~having~~has its full value or ~~being~~in which the value is completely absent should be ~~checked~~considered.[46]

(b) If the strength design method is used, the following load combinations should be considered:

(1) 1.4 D + 1.7 L

(2) 1.4 D + 1.7 L + 1.9 E

(3) 1.4 D + 1.7 L + 1.7 W

If thermal stresses due to T_0 and R_0 are present, the following combinations should also be considered:

(4) $(0.75)(1.4D + 1.7L + 1.7T_0 + 1.7R_0)$

(5) $(0.75)(1.4D + 1.7L + 1.9E + 1.7T_0 + 1.7R_0)$

(6) $(0.75)(1.4D + 1.7L + 1.7W + 1.7T_0 + 1.7R_0)$

In addition, the following combination~~s~~ should be considered:

(7) 1.2 D + 1.9 E

(8) 1.2 D + 1.7 W

(ii) For factored load conditions which represent extreme environmental, abnormal, abnormal/severe environmental, and abnormal/extreme environmental conditions, the strength design method should be used and the following load combinations should be considered:

(a) $D + L + T_0 + R_0 + E'$

(b) $D + L + T_0 + R_0 + W_t$

(c) $D + L + T_a + R_a + 1.5\ P_a$

(d) $D + L + T_a + R_a + 1.25\ P_a + 1.0\ (Y_r + Y_j + Y_m) + 1.25\cancel{E'}E$[47]

(e) $D + L + T_a + R_a + 1.0\ P_a + 1.0\ (Y_r + Y_j + Y_m) + 1.0\ E'$

In combinations II.3(b)(ii)[48](b), (d), and (e), the maximum values of P_a, T_a, R_a, Y_j, Y_r, and Y_m, including an appropriate dynamic load factor, should be used unless a time-history analysis is performed to justify otherwise. Combinations II.3(b)(ii)(b)~~, and~~[49] (d) and (e) and the corresponding structural acceptance criteria of subsection I.5 of this SRP section should be satisfied first without the tornado missile load in (b) and without Y_r, Y_j, and Y_m in (d) and (e). When considering these concentrated loads, local section strength capacities may be exceeded provided there will be no loss of function of any safety-related system.

Where any load reduces the effects of other loads, the corresponding coefficient for that load should be taken as 0.9 if it can be demonstrated that the load is always present or occurs simultaneously with other loads. Otherwise the coefficient for that load should be taken as zero.

Where the structural effects of differential settlement, creep, or shrinkage may be significant, they should be included with the dead load, D, as applicable.

c. Load Combinations for Steel Structures

For steel interior structures, the load combinations are acceptable if found in accordance with the following:

(i) For service load conditions, either the elastic working stress design methods of ~~Part 1 of the AISC specifications~~Section Q1 of ANSI/AISC N690-1984, supplemented by Appendix F to this SRP section,[50] or the plastic design methods of ~~Part 2 of the AISC~~ Section Q2 of ANSI/AISC N690-1984, supplemented by Appendix F to this SRP section,[51] may be used.

(a) If the elastic working stress design methods are used, the following load combinations should be considered:

(1) $D + L$

(2) $D + L + E$

(3) $D + L + W$

If thermal stresses due to T_0 and R_0 are present, the following combinations should be also be considered:

(4) $D + L + T_0 + R_0$

(5) $D + L + T_0 + R_0 + E$

(6) $D + L + T_0 + R_0 + W$

(b) If plastic design methods are used, the following load combinations should be considered:

(1) $1.7\ D + 1.7\ L$

(2) $1.7\ D + 1.7\ L + 1.7\ E$

(3) $1.7\ D + 1.7\ L + 1.7\ W$

If thermal stresses due to T_0 and R_0 are present, the following combinations should also be considered:

(4) $1.3\ (D + L + T_0 + R_0)$

(5) $1.3(D + L + E + T_0 + R_0)$

(6) $1.3\ (D + L + W + T_0 + R_0)$

(ii) For factored load conditions, the following load combinations should be considered:

(a) If elastic working stress design methods are used:

(1) $D + L + T_0 + R_0 + E'$

(2) $D + L + T_0 + R_0 + W_t$

(3) $D + L + T_a + R_a + P_a$

(4) $D + L + T_a + R_a + P_a + 1.0\ (Y_r + Y_j + Y_m) + E$

(5) $D + L + T_a + R_a + P_a + 1.0\ (Y_r + Y_j + Y_m) + E'$

(b) If plastic design methods are used:

(1) $D + L + T_0 + R_0 + E'$

(2) $D + L + T_0 + R_0 + Wt$

(3) $D + L + T_a + R_a + 1.5\ P_a$

(4) $D + L + T_a + R_a + 1.25\ P_a + 1.0\ (Y_r + Y_j + Y_m) + 1.25\ E$

(5) $D + L + T + R_a + 1.0\ P_a + 1.0\ (Y_r + Y_j + Y_m) + E'$

In the above factored load combinations, thermal loads can be neglected when it can be shown that they are secondary and self-limiting in nature and where the material is ductile.

In combinations II.3.c(ii)(b)[52](3), (4), and (5), the maximum values of P_a, T_a, R_a, Y_j, Y_r, and Y_m, including an appropriate dynamic load factor, should be used unless a time-history analysis is performed to justify otherwise. Combinations II.3.c(ii)(b)[53](2), (4) and (5) and the corresponding structural acceptance criteria of subsection II.5 of this SRP section should first be satisfied without the tornado missile load in (2) and without Y_r Y_j, and Y_m in (4) and (5).

When considering these concentrated loads, local section strength may be exceeded provided there will be no loss of function of any safety-related system.

Where any load reduces the effects of other loads, the corresponding coefficient for that load should be taken as 0.9, if it can be demonstrated that the load is always present or occurs simultaneously with other loads. Otherwise, the coefficient for that load should be taken as zero.

Where the structural effect of differential settlement may be significant, it should be included with the dead load, D.

4. Design and Analysis Procedures

The design and analysis procedures utilized for Category I structures, including assumptions on boundary conditions and expected behavior under loads, are acceptable if found in accordance with the following:

a. For concrete structures, the procedures are in accordance with ACI-349, "Code Requirements for Nuclear Safety Related Structures," ~~(Ref. 1)~~[54]supplemented by Regulatory Guide 1.142 and Appendix E to this SRP section.[55]

b. For steel structures, the procedures are in accordance with ~~the AISC "Specification..."~~ANSI/AISC N690-1984, supplemented by Appendix F to this SRP section[56] ~~(Ref. 3)~~.[57]

c. Computer programs are acceptable if the validation provided is found in accordance with procedures delineated in subsection II.4.e of SRP Section 3.8.1.

d. Design report is considered acceptable if it contains the information specified in Appendix C to this SRP section.

e. Structural audit is conducted in accordance with the provisions of Appendix B to this SRP section.

f. Design of spent fuel pool and rods is considered acceptable when the requirements of Appendix D to this SRP section are met.

g. Consideration of dynamic lateral soil pressures on earth retaining walls and embedded walls is acceptable when the requirements of Appendix G to this SRP section are met.[58]

h. Design of masonry walls is considered acceptable when the requirements of Appendix A are met.[59]

5. Structural Acceptance Criteria

For each of the loading combinations delineated in subsection II.3 of this SRP section, the following defines the allowable limits which constitute the structural acceptance criteria:

a. In Combinations for Concrete

In Combinations for Concrete	Limit
Paragraphs II.3.b(i)(a)(1), (2), and (3)	S(1)
Paragraphs II.3.b(i)(a)(4), (5), and (6)	1.3S
Paragraphs II.3.b(i)(b)(1), (2), and (3)	U(2)
Paragraphs II.3.b(i)(b)(4), (5), and (6)	U
Paragraphs II.3.b(i)(b)(6), (7), and (8)	U
Paragraphs II.3.b(ii)(a), (b), (c), (d), and (e)	U

b. In Combinations for Steel

In Combinations for Steel	Limit
Paragraphs II.3.c(i)(a)(1), (2), and (3)	S
Paragraphs II.3.c(i)(a)(4), (5), and (6)	1.5 S
Paragraphs II.3.c(i)(b)(1), (2), and (3)	Y(3)
Paragraphs II.3.c(i)(b)(4), (5), and (6)	Y
Paragraphs II.3.c(ii)(a)(1), (2), (3)(4), and (4)	1.6 S
Paragraphs II.3.c(ii)(a)(4)(4), and (5)	1.7 S
Paragraphs II.3.c(ii)(b)(1), (2), (3), (4), and (5)	Y

Notes

(1) S - For concrete structures, S is the required section strength based on the working stress design method and the allowable stresses defined in the[60] ACI 318 Code.

For structural steel, S is the required section strength based on elastic design methods and the allowable stresses defined in ~~Part 1 of the AISC "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings."(Ref. 3)~~Part Q1 of the ANSI/AISC N690-1984.[61]

The one-third increase in allowable stresses for concrete and steel due to seismic or wind loadings is not permitted.

(2) U - For concrete structures, U is the section strength required to resist design loads based on the strength design methods described in ACI 349 Code ~~(Ref. 1)~~.[62]

(3) Y - For structural steel, Y is the section strength required to resist design loads and based on plastic design methods described in Part 2 of ~~the~~ ANSI/AISC N690-1984 ~~"Specification for the Design, Fabrication and Erection of Structural Steel for Buildings" (Ref. 3)~~.[63]

(4) - For these two combinations, in computing the required section strength, S, the plastic section modulus of steel shapes, except for those which do not meet the ~~AISC~~ANSI/AISC N690-1984[64] criteria for compact sections, may be used.

6. Materials, Quality Control, and Special Construction Techniques

For Category I structures outside the containment, the acceptance criteria for materials, quality control, and any special construction techniques are in accordance with the codes and standards indicated in subsection I.6 of SRP Section 3.8.3, as applicable.

7. Testing and Inservice Surveillance Requirements

At present there are no special testing or inservice surveillance requirements for Category I structures outside the containment. However, where some requirements become necessary for special structures, such requirements are reviewed on a case-by-case basis.

8. Masonry Walls

Acceptance criteria for masonry walls are contained in Appendix A to this SRP section.

Technical Rationale[65]

The technical rationale for application of these acceptance criteria is discussed in the following paragraphs:[66]

1. Compliance with 10 CFR 50.55a requires that structures, systems, and components be designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed and specifies that suitable optional Code Cases be applied to such structures, systems, and components.

   SRP Section 3.8.4 cites Regulatory Guides 1.69, 1.91, 1.94, 1.115, 1.142, and 1.143 to provide guidance regarding construction, quality control, tests, and inspections that are acceptable to the staff. ACI 349 and ANSI/AISC N690-1984 contain basic specifications for concrete and steel structures, respectively. These guides and specifications impose specific restrictions to ensure that structures, systems, and components will perform their intended safety function.

   Meeting these requirements provides added assurance that the structures, systems, and components described herein will perform their safety function and limit the release of radioactive materials.[67]

2. Compliance with GDC 1 requires that structures, systems, and components be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed.

   SRP Section 3.8.4 cites ACI 349, supplemented by Regulatory Guides 1.94 and 1.142, to provide guidance describing design methodology, materials testing, and construction techniques that are commensurate with the importance of the safety function to be performed. Conformance with these requirements imposes specific restrictions to ensure that structures other than the containment will perform acceptably, commensurate with their intended safety function, when designed in accordance with the above standards.

   Meeting these requirements provides added assurance that the structures, systems, and components described herein will perform their intended safety function.[68]

3. Compliance with GDC 2 requires that systems, structures, and components important to safety be designed to withstand the effects of expected natural phenomena combined with the effects of normal and accident conditions without loss of capability to perform their safety function.
   The primary function of structures other than the containment is to house safety-related equipment, protecting it from the effects of natural phenomena so that it can perform its function as needed. Consequently, it is necessary to specify the most severe natural phenomena event that may occur as a function of the frequency of occurrence. Structures that house safety-related equipment must be designed to withstand the loads specified within an adequate margin. Load combinations and specifications cited in this SRP section provide engineering criteria that are acceptable to the staff for accomplishing that function.

Meeting this requirement provides added assurance that equipment and structures will be designed to withstand effects of natural phenomena and will perform their intended safety function.[69]

4. Compliance with GDC 4 requires that structures important to safety shall be designed to accommodate the effects of and to be compatible with environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including LOCAs. These structures shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharge fluids, that may result from equipment failures and from events outside the nuclear power unit.

   The requirements of GDC 4 will ensure a suitable and controlled operating environment for structures, systems, and components important to safety during normal operation, during adverse environmental occurrences, and during and subsequent to postulated accidents, including LOCAs. SRP Section 3.8.4 cites Appendix C to ACI 349 and Regulatory Guides 1.91 and 1.115 to provide appropriate design criteria against dynamic loads.

   Meeting these requirements provides added assurance that structures will not fail to function as designed, thus providing protection against loss of their structural integrity.[70]

5. Compliance with GDC 5 prohibits the sharing of structures important to safety by nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety function, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining units.

   The requirements of GDC 5 are imposed to ensure that the use of common structures in multiple-unit plants will not significantly affect the orderly and safe shutdown and cooldown in one plant in the event of an accident in another. Loads from normal operation and design basis accidents are combined in the load combination equations so that the resulting structural designs provide for mutual independence of shared structures.

   Meeting this requirement provides added assurance that structures other than the containment and its associated components are capable of performing their required safety function even if they are shared by multiple nuclear power units.[71]

6. Compliance with Appendix B to 10 CFR Part 50 requires that applicants establish and maintain a quality assurance program (including design, testing, and records control) as outlined therein.

   SRP Section 3.8.4 provides guidance specifically related to design and testing of structural concrete and steel during the construction of nuclear power plants. Subsection II.2 of this SRP section cites Regulatory Guide 1.94, which in turn cites ANSI N45.2.5-1974 to satisfy, with exceptions, the requirements of Appendix B to 10 CFR Part 50.

Meeting these requirements provides added assurance that structures covered in this SRP section will meet the requirements of Appendix B to 10 CFR Part 50 and thus perform their intended safety function.[72]

III. REVIEW PROCEDURES

The reviewer selects and emphasizes material from the review procedures described below, as may be appropriate for a particular case.

1. Description of the Structures

After the type of structure and its functional characteristics are identified, information on similar and previously licensed plants is obtained for reference. Such information, which is available in safety analysis reports and amendments of previous license applications, enables identification of differences for the case under review. These differences require additional scrutiny and evaluation. New and unique features that have not been used in the past are of particular interest and are thus examined in greater detail. The information furnished in the SAR is reviewed for completeness in accordance with the ~~"Standard Format..." (Ref. 4)~~Regulatory Guide 1.70.[73] A decision is then made with regard to the sufficiency of the descriptive information provided. Any additional required information not provided is requested from the applicant at an early stage of the review process.

2. Applicable Codes, Standards, and Specifications

The list of codes, standards, guides, and specifications is compared with the list in subsection II.2 of this SRP section. The reviewer ~~assures himself~~ verifies[74] that the appropriate code or guide is utilized and that the applicable edition and stated effective addenda are acceptable.

3. Loads and Loading Combinations

The reviewer verifies that the loads and load combinations are as conservative as those specified in subsection II.3 of this SRP section. Any deviations from the acceptance criteria for loads and load combinations that have not been adequately justified are identified as unacceptable and transmitted to the applicant.

4. Design and Analysis Procedures

The reviewer ~~assures himself~~ verifies[75] that for the design and analysis procedures, the applicant is utilizing the ACI-349 Code ~~(Ref. 1)~~[76] and ~~the AISC~~ANSI/AISC N690-1984[77] Specifications for concrete and steel structures ~~(Ref. 3)~~,[78] respectively.

Any computer programs that are utilized in the design and analysis of the structure are reviewed to verify their validity in accordance with the acceptance criteria delineated in subsection II.4.e of SRP Section 3.8.1.

The reviewer ~~assures~~ensures[79] that the provisions specified in subsection II.4 of this SRP section regarding design report, structural audits and design of spent fuel pool and racks are met.

5. Structural Acceptance Criteria

The limits on allowable stresses and strains in the concrete, reinforcement, structural steel, etc., are compared with the corresponding allowable stresses specified in subsection II.5 of this SRP section. If the applicant proposes to exceed some of these limits for some of the load combinations and at some localized points on the structure, the justification provided to show that the structural integrity of the structure will not be affected is evaluated. If such justification is determined to be inadequate, the proposed deviations are identified and transmitted to the applicant with a request for the required additional justification and bases.

6. Materials, Quality Control, and Special Construction Techniques

The materials, quality control procedures, and any special construction techniques are compared with those referenced in subsection II.6 of this SRP section. If a new material not used in prior licensed cases is utilized, the applicant is requested to provide sufficient test and user data to establish the acceptability of such a material. Similarly, any new quality control procedures or construction techniques are reviewed and evaluated to ~~assure~~ ensure[80] that there will be no degradation of structural quality that might affect the structural integrity of the structure.

7. Testing and Inservice Surveillance Requirements

Any testing and inservice surveillance programs are reviewed on a case-by-case basis.

8. Masonry Walls

The reviewer should ~~assure~~ ensure[81] that the requirements identified in Appendix A to this SRP section are met.

In the ABWR and System 80+ design certification FSERs the Staff accepted an exemption to 10 CFR 100 Appendix A requirement that all safety-related SSCs be designed to remain functional and within applicable stress and deformation limits when subjected to an OBE. The Staff reviewed the controlling load combinations and concluded that, in most cases, load combinations incorporating OBE loads will not control the design of either steel or concrete structures. As a result, the Staff concluded that there would be no reduction in the safety margin of steel and concrete structures due to the elimination of the OBE as a design requirement.[82]

For standard design certification reviews under 10 CFR Part 52, the procedures above should be followed, as modified by the procedures in SRP Section 14.3 (proposed), to verify that the design set forth in the standard safety analysis report, including inspections, tests, analysis, and acceptance criteria (ITAAC), site interface requirements and combined license action items, meet the acceptance criteria given in subsection II. SRP Section 14.3 (proposed) contains procedures for the review of certified design material (CDM) for the standard design, including the site parameters, interface criteria, and ITAAC.[83]

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided to satisfy the requirements of this SRP section and concludes that ~~his~~the[84] evaluation is sufficiently complete and adequate to support the following type of conclusive statement to be included in the staff's safety evaluation report (SER):[85]

The staff concludes that the design of safety-related structures other than containment or containment interior structures ~~are~~is[86] acceptable and meets the relevant requirements of 10 CFR ~~Part 50,~~50.55a and General Design Criteria 1, 2, 4, and 5. This conclusion is based on the following:

1. The applicant has met the requirements of 50.55a and GDC 1 with respect to ~~assuring~~ ensuring[87] that the safety-related structures other than containment are designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with its safety function to be performed by meeting the guidelines of regulatory guides and industry standards indicated below.

2. The applicant has met the requirements of GDC 2 by designing the safety-related structures ~~other than containment~~ described in this section[88] to withstand the most severe earthquake that has been established for the site with sufficient margin and the combinations of the effects of normal and accident conditions with the effects of environmental loadings such as earthquakes and other natural phenomena.

3. The applicant has met the requirements of GDC 4 by ~~assuring~~ ensuring[89] that the design of the safety-related structures are such that they are[90] capable of withstanding the dynamic effects associated with missiles, pipe whipping, and discharging fluids.

4. The applicant has met the requirements of GDC 5 by demonstrating that structures, systems, and components are not shared between units or that, if shared, they have demonstrated that sharing will not impair their ability to perform their intended safety function.

5. The applicant has met the requirements of Appendix B because the quality assurance program provides adequate measures for implementing guidelines relating to structural design audits.

6.[91] The criteria used in the analysis, design, and construction of all the plant Category I structures to account for anticipated loadings and postulated conditions that may be imposed upon each structure during its service lifetime are in conformance with established criteria, codes, standards, and specifications acceptable to the regulatory staff. These include meeting the positions of Regulatory Guides ~~1.10, 1.15, 1.55,~~[92] 1.69, 1.91, 1.94, 1.115, 1.142, and 1.143 and industry standards ACI-349 and ~~AISC, "Specifications~~

~~for the Design, Fabrication and Erection of Structural Steel for Buildings."~~ANSI/AISC N690-1984.

7.[93] The use of these criteria as defined by applicable codes, standards, and specifications; the loads and loading combinations; the design and analysis procedures; the structural acceptance criteria; the materials, quality control, and special construction techniques; and the testing and inservice surveillance requirements provide reasonable assurance that, in the event of winds, tornadoes, earthquakes, and various postulated accidents occurring within the structures, the structures will withstand the specified design conditions without impairment of structural integrity or the performance of required safety functions.

For design certification reviews, the findings will also summarize, to the extent that the review is not discussed in other safety evaluation report sections, the staff's evaluation of inspections, tests, analyses, and acceptance criteria (ITAAC), including design acceptance criteria (DAC), site interface requirements, and combined license action items that are relevant to this SRP section.[94]

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

This SRP section will be used by the staff when performing safety evaluations of license applications submitted by applicants pursuant to 10 CFR 50 or 10 CFR 52.[95] Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications docketed six months or more after the date of issuance of this SRP section.[96]

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides.

VI. REFERENCES

1. ACI 349-1976 (S79), "Code Requirements for Nuclear Safety-Related Structures," American Concrete Institute.[97]

2. Regulatory Guide 1.142, "Safety-Related Concrete Structures for Nuclear Power Plants."

3. ~~AISC, "Specification for Design, Fabrication and Erection of Structural Steel for Buildings," American Institute of Steel Construction.~~ANSI/AISC N690-1984, "Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities."[98]

4. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants."

5. 10 CFR Part 50, 50.55a, "Codes and Standards."

6. 10 CFR Part 50, Appendix A, General Design Criterion 1, "Quality Standards and Records."

7. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."

8. 10 CFR Part 50, Appendix A, General Design Criterion 4, ~~"Environmental and Missile Design Bases."~~"Environmental and Dynamic Effects Design Bases."[99]

9. 10 CFR Part 50, Appendix A, General Design Criterion 5, "Sharing of Structures, Systems, and Components."

10. 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants."

~~11. Regulatory Guide 1.10, "Mechanical (Cadweld) Splices in Reinforcing Bars of Category I Concrete Structures."~~

~~12. Regulatory Guide 1.15, "Testing or Reinforcing Bars for Category I Concrete Structures."~~

~~13. Regulatory Guide 1.55, "Concrete Placement in Category I Structures."~~[100]

~~14~~11.[101] Regulatory Guide 1.69, "Concrete Radiation Shields for Nuclear Power Plants."

~~15~~12.[102] Regulatory Guide 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants."

~~16~~13.[103] Regulatory Guide 1.94, "Quality Assurance Requirements for Installation, Inspection, and Testing of Structural Concrete."

~~17~~14.[104] Regulatory Guide 1.115, "Protection Against Low Trajectory Turbine Missiles."

~~18~~15.[105] Regulatory Guide 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in LWR Plants."

16. ACI-318-77, "Building Code Requirements for Reinforced Concrete," American Concrete Institute.[106]

APPENDIX A TO SRP SECTION 3.8.4

~~INTERIM~~[107] CRITERIA FOR SAFETY-RELATED MASONRY WALL EVALUATION

The purpose of this appendix is to provide minimum design considerations and criteria for the review of safety-related masonry walls which will meet the design standards specified in subsection II of this SRP section.

1. General Requirements

The materials, testing, analysis, design, construction, and inspection related to the design and construction of safety-related concrete masonry walls should conform to the applicable requirements contained in Uniform Building Code - 1979, unless specified otherwise, by the provisions to this criteria.

The use of other industrial codes, such as ACI-531, ATC-3, or NCMA, is also acceptable. However, when the provisions of these codes are less conservative than the corresponding provisions of these ~~interim~~[108] criteria, their use should be justified on a case-by-case basis.

In new construction, no unreinforced masonry walls will be permitted. ~~For operating plants, existing unreinforced walls will be evaluated by the provisions of these criteria. Plants applying for operating licenses which have already built unreinforced masonry walls will be evaluated on a case-by-case basis.~~[109]

2. Loads and Load Combinations

The loads and load combinations shall include consideration of normal loads, severe environmental loads, extreme environmental load, and abnormal loads. ~~Specifically, for operating plants, the load combinations provided in the plant's FSAR shall govern. For operating license applications,~~[110] The following load combinations shall apply (for definition of load terms, see SRP Section 3.8.4, subsection II.3).

(a) Service Load Conditions

(1) D + L

(2) D + L + E

(3) D + L + W

If thermal stresses due to T_0 and R_0 are present, they should be included in the above ~~containment~~combinations,[111] as follows:

(1a) $D + L + T_0 + R_0$

(1b) $D + L + T_0 + R_0 + E$

(1c) $D + L + T_0 + R_0 + W$

Check load combination for controlling condition for maximum 'L' and for no 'L'.

(b) Extreme Environmental, Abnormal, Abnormal/Severe Environmental, and Abnormal/Extreme Environmental Conditions

(4) $D + L + T_0 + R_0 + E'$

(5) $D + L + T_0 + R_0 + W_t$

(6) $D + L + T_a + R_a + 1.5\ P_a$

(7) $D + L + T + R_a + 1.25\ P_a + 1.0\ (Y_r + Y_j + Y_m) + 1.25\ E$

(8) $D + L + T_a + R_a + 1.0\ P_a + 1.0\ (Y_r + Y_j + Y_m) + 1.0\ E'$

In combinations (6), (7), and (8) the maximum values of P_a, T_a, R_a, Y_r, Y_j, and Y_m, including an appropriate dynamic load factor, should be used unless a time-history analysis is performed to justify otherwise. Combinations (5), (7), and (8) and the corresponding structural acceptance criteria of should be satisfied first without the tornado missile load in (5) and without Y_r, Y_j, and Y_m in (7) and (8). When considering these loads, local section strength capacities may be exceeded under these concentrated loads, provided there will be no loss of function of any safety-related system.

Both cases of L having its full value or being completely absent should be checked.

3. Allowable Stresses

Allowable stresses provided in ACI-531-79, as supplemented by the following modifications/exceptions, shall apply.

(a) When wind or seismic loads (OBE) are considered in the loading combinations, no increase in the allowable stresses is permitted.

(b) Use of allowable stresses corresponding to special inspection category shall be substantiated by demonstration of compliance with the inspection requirements of the NRC criteria.

(c) ~~When tension perpendicular to bed joints is used in qualifying the unreinforced masonry walls, the allowable value will be justified by test program or other means pertinent to the plant and loading conditions. For reinforced masonry walls,~~[112] All the tensile stresses will be resisted by reinforcement.

(d) For load conditions which represent extreme environmental, abnormal, abnormal/severe environmental, and abnormal/extreme environmental conditions, the allowable working stress may be multiplied by the factors shown in the following table:

Type of Stress	Factor
Axial or Flexural Compression[1]	2.5
Bearing	2.5
Reinforcement stress except shear	2.0 but not to exceed 0.9 fy
Shear reinforcement and/or bolts	1.5
Masonry tension parallel to bed joint	1.5
Shear carried by masonry	1.3
Masonry tension perpendicular to bed joint	
for reinforced masonry	0
~~for unreinforced masonry[2]~~	~~1.3~~[113]

Note~~s~~:

~~(1)~~ When anchor bolts are used, the[114] design should prevent facial spalling of masonry unit.

~~(2) See 3(c).~~[115]

4. Design and Analysis Considerations

(a) The analysis should follow established principles of engineering mechanics and take into account sound engineering practices.

(b) Assumptions and modeling techniques used shall give proper considerations to boundary conditions, cracking of sections, if any, and the dynamic behavior of masonry walls.

(c) Damping values to be used for dynamic analysis shall be those for reinforced concrete given in Regulatory Guide 1.61.

(d) ~~In general, for operating plants, the seismic analysis and Category I structural requirements of FSAR shall apply. For other plants, corresponding SRP requirements shall apply.~~[116] The seismic analysis shall account for the variations and uncertainties in mass, materials, and other pertinent parameters used.

(e) The analysis should consider both in-plane and out-of-plane loads.

(f) Interstory drift effects should be considered.

(g) In new construction, no unreinforced masonry wall is permitted; also, all grout in concrete masonry walls shall be ~~compared~~consolidated[117] by vibration.

(h) For masonry shear walls, the minimum reinforcement requirements of ACI-531 shall apply.

(i) Special construction (e.g., multiwythe, composite) or other items not covered by the code shall be reviewed on a case-by-case basis for their acceptance.

(j) ~~Licensees or~~[118] Applicants shall submit QA/QC information, if available, for staff review.

In the event QA/QC information is not available, a field survey and a test program reviewed and approved by the staff shall be implemented to ascertain the conformance of masonry construction to design drawings and specifications (e.g., rebar and grouting).

(k) For masonry walls requiring protection from spalling and scabbing due to accident pipe reaction (Y_r),jet impingement (Y_j), and missile impact (Y_m), the requirements of SRP Section 3.5.3 shall apply. Any deviation from SRP Section 3.5.3 shall be reviewed and approved on a case-by-case basis.

5. Revision of Criteria

The criteria will be revised, as appropriate, based on:

~~(a) Design review meetings with the selected licensees and their A/Es.~~[119]

~~(b)~~(a)[120] Experience gained during review.

~~(c)~~(b)[121] Additional information developed through testing and researches.

6. References

(a) Uniform Building Code - 1979 Edition.

(b) Building Code Requirements for Concrete Masonry Structures ACI-531-79 and Commentary ACI-531R-79.

(c) Tentative Provisions for the Development of Seismic Regulations for Buildings-Applied Technology Council ATC 3-06.

(d) Specification for the Design and Construction of Load-Bearing Concrete Masonry - NCMA August, 1979.

(e) Trojan Nuclear Plant Concrete Masonry Design Criteria Safety Evaluation Report Supplement - November, 1980.

(f) Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants."

APPENDIX B TO SRP SECTION 3.8.4
STRUCTURAL DESIGN AUDITS

1. Introduction

Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires, in part, that the design control measures shall provide for verifying or checking the adequacy of simplified calculational methods, or by the performance of a suitable testing program. This appendix provides requirements and guidelines for implementation of structural design audits.

2. Objectives

The audit is conducted in order that the following objectives are accomplished:

(a) To investigate the manner in which the applicant has implemented the structural design criteria that he committed to use for the facility.

(b) To verify that the key structural design calculations have been conducted in an acceptable way.

(c) To identify and assess the safety significance of these areas where the plant structures were designed and analyzed using methods other than those recommended by the SRP section.

3. Preliminary Arrangements

Arrangements for the audit are to be made by the Licensing Project Manager (LPM). The audit agenda, including specific areas of interest are prepared by the reviewer and forwarded to the applicant at least thirty (30) days prior to the date of the audit. The LPM should notify the appropriate I&E regional office personnel as well as any intervening parties, if applicable, about the forthcoming audit.

4. Conduct of the Audit

(a) An Overview of the Plant Design:

The applicant should present an overview of each of the key structures including a brief description, assumptions, modeling techniques, and technique features of design as well as any deviations from those committed to in the SARs.

(b) Audit of Design Calculations:

The auditing personnel review the design calculations for the structures which have been identified during the review of the applicant's Design Report. Any questions such as those regarding the structural modeling, analysis, proportioning of the members, and computer runs should be discussed among the participants in the audit and resolved. If such a resolution required additional engineering data and further analysis on the part of the applicant, the specific followup action items should be identified and noted in the meeting minutes for subsequent resolution.

5. Exit Meeting

An exit meeting is held at the conclusion of the audit to discuss and summarize the audit findings, generic issues pertaining to the design, specific action items, and the schedules for resolution of the action items.

6. Minutes of the Audit

The LPM is responsible for preparation of the audit minutes.

7. After-Audit Meetings

Review of the applicant's response to the action items may necessitate additional meeting(s) between the staff and the applicant to explain certain parts of the responses.

8. Input to the SER

The audit should be considered as an integral part of the review process. Resolution of the action items, together with appropriate consideration of other safety aspects should constitute the major basis for the staff's preparation of the SER.

APPENDIX C TO SRP SECTION 3.8.4

DESIGN REPORT

Category I Structures

I. OBJECTIVE

The primary objective of the Design Report, provided by the applicant,[122] is to provide the reviewer with design and construction information more specific than that contained in the SARs which can assist ~~him~~the reviewer[123] to plan and conduct a structural audit. For this review, the information must be in quantitative form representing the scope of the actual design computations and the final design results.

II. STRUCTURAL DESCRIPTION AND GEOMETRY

1. Structural Geometry and Dimensions
2. Key Structural Elements and Description
3. Floor Layout and Elevations
4. Conditions of Vicinity and Supports
5. Special Structural Features

III. STRUCTURAL MATERIAL REQUIREMENTS

1. Concrete

a) Compressive Strength

b) Modulus of Elasticity

c) Shear Modulus

d) Poisson's Ratio

2. Reinforcement

a) Yield Stress

b) Tensile Strength

c) Elongation

3. Structural Steel

    a) Grade

    b) Ultimate Tensile Strength

    c) Yield Stress

4. Prestressing Stage (if applicable)

    a) Type of the System (manufacturer)

    b) Description of Tendons

    c) Description of Surcharge

    d) Tendons and Sheeting Layout

    e) Dome Prestressing

5. Foundation Media

    a) General Description

    b) Unit Weight

    c) Shear Modulus

    d) Angle of Internal Friction

    e) Cohesion

    f) Bearing Capacity

6. Special Considerations

IV. <u>STRUCTURAL LOADS</u>

1. Live and Dead Load Floor Plans

2. Determination of Transient and Dynamic Loads

3. Manufacturer's Data of Equipment Loads

4. Environmental Loads

5. Torsional Effects

V. STRUCTURAL ANALYSIS AND DESIGN

1. Design Computations of Critical Elements

2. Stability Calculations

3. Engineering Drawings Including Details of Connections and Joints

4. Discussion of Unique Features and Problem Resolution

VI. SUMMARY OF RESULTS

1. The Required Sections

2. The Provided Sections

3. Breakdown of Individual Load Contributions

4. Tabulation of Capacities of the Section Versus Capacities Required for Different Failure Modes (Bending, Shear, Axial Load)

5. Margins of Safety Provided

VII. CONCLUSIONS

APPENDIX D TO SRP SECTION 3.8.4

TECHNICAL POSITION ON SPENT FUEL POOL RACKS

Introduction

Spent fuel pool racks are classified in Reference 1.1 as Seismic Category I structures.[124]

The purpose of this appendix is to provide minimum requirements and criteria for review of spent fuel pool racks and the associated structures which would meet the design standards specified in subsection II of this SRP section.

(1) Description of the Spent Fuel Pool and Racks

Descriptive information including plants and sections showing the spent fuel pool in relation to other plant structures shall be provided in order to define the primary structural aspects and elements relied upon to perform the safety-related functions of the pool, the spent pool liner fuel, and the racks. The main safety function of the spent fuel pool, including the liner, and the racks is to maintain the spent fuel assemblies in a safe configuration through all environmental and abnormal loadings such as earthquake, and impact due to spent fuel cask drop, drop of a spent fuel assembly, or drop of any other heavy object during routine spent fuel handling.

The major structural elements reviewed and the extent of the descriptive information required are indicated below.

(a) Support of the Spent fuel Racks: The general arrangements and principal features of the horizontal and the vertical supports to the spent fuel racks should be provided indicating the methods of transferring the loads on the racks to the fuel pool wall and the foundation slab. All gaps (clearance or expansion allowance) and sliding contacts should be indicated. The extent of interfacing between the new rack system and the old fuel pool walls and base slab should be discussed, i.e., interface loads, response spectra, etc.

If connections of the racks are made to the base and to the side walls of the pool such that the pool liner may be perforated, the provisions for avoiding leakage of radioactive water of the pool should be indicated.

(b) Fuel handling: Postulation of a drop accident and quantification of the drop parameters are reviewed by the ~~Accident Evaluation Branch (AEB)~~Emergency Preparedness and Radiation Protection Branch (PERB);[125] ~~Structural Engineering Branch~~ Civil Engineering and Geosciences Branch[126] accepts the findings of the ~~AEB~~PERB[127] review for the purpose of review of the integrity of the racks and the fuel pool including the fuel pool lines due to a postulated fuel handling accident. Sketches and sufficient details of the fuel handling system should be provided to facilitate this review.

(2) Applicable Codes, Standards, and Specifications

Construction materials should conform to Section III, Subsection NF of Ref. 3.1. All materials should be selected to be compatible with the fuel pool environment to minimize corrosion and galvanic effects.

Design, fabrication, and installation of spent fuel racks of stainless steel material may be performed based upon Subsection NF requirements of Ref. 3.1 for Class 3 component supports.

(3) Seismic and Impact Loads

For plants where dynamic input data such as floor responses spectra or ground response spectra are not available, necessary dynamic analyses may be performed using the criteria described in SRP Section 3.7. The ground response spectra and damping values should correspond to Regulatory Guides 1.60 and 1.61, respectively. For plants where dynamic data are available, e.g., ground response spectra for a fuel pool supported by the ground, floor response spectra for fuel pools supported on soil where soil-structure interaction was considered in the pool design or a floor response spectra for a fuel pool supported by the reactor building, the design and analysis of the new rack system may be performed by using either the existing input parameters including the old damping values or new parameters in accordance with Regulatory Guides 1.60 and 1.61. The use of existing input with new damping values in Regulatory Guide 1.61 is not acceptable.

Seismic excitation along three orthogonal directions should be imposed simultaneously for the design of the new rack system.

The peak response from each direction should be combined by square root of the sum of the squares in accordance with Regulatory Guide 1.92. If response spectra are available for a vertical and horizontal directions only, the same horizontal response spectra may be applied along the other horizontal direction.

Submergence in water may be taken into account. The effects of submergence are considered on case-by-case basis.

Due to gaps between fuel assemblies and the walls of the guide tubes, additional loads will be generated by the impact of fuel assemblies during a postulated seismic excitation. Additional loads due to this impact effect may be determined by estimating the kinetic energy of the fuel assembly. The maximum velocity of the fuel assembly may be estimated to be the spectral velocity associated with the natural frequency of the submerged fuel assembly. Loads thus generated should be considered for local as well as overall effects on the walls of the rack and the supporting framework. It should be demonstrated that the consequent loads on the fuel assembly do not lead to a damage of the fuel.

Loads generated from other postulated impact events may be acceptable, if the following parameters are described: the total mass of the impacting missile, the maximum velocity at the time of impact, and the ductility ratio of the target material utilized to absorb the kinetic energy.

(4) Loads and Load Combinations:

Any change in the temperature distribution due to the proposed modification should be identified. Information pertaining to the applicable design loads and various combinations thereof should be provided indicating the thermal load due to the effect of the maximum temperature distribution through the pool walls and base slab. Temperature gradient across the rack structure due to differential heating effect between a full and an empty cell should be indicated and incorporated in the design of the rack structure. Maximum uplift forces available from the crane should be indicated including the consideration of these forces in the design of the racks and the analysis of the existing pool floor, if applicable.

The fuel pool racks, the fuel pool structure including the pool slab and fuel pool liner, should be evaluated for accident load combinations which include the impact of the spent fuel cask, the heaviest postulated load drop, and/or accidental drop of fuel assembly from maximum height.

The acceptable limits (strain or stress limits) in this case will be reviewed on a case-by-case basis but in general the applicant is required to demonstrate that the functional capability and/or the structural integrity of each component is maintained. Guidance regarding service limits and load combinations is provided in References 1.4 and 3.1.[128]

The specific loads and load combinations are acceptable if they are in conformity with the applicable portions of SRP Section 3.8.4, subsection II.3, and Table 1.

(5) Design and Analysis Procedures

General information regarding design of spent fuel pool racks can be found in Reference 3.2.[129]

Details of the mathematical model including a description of how the important parameters are obtained should be provided including the following: The methods used to incorporate any gaps between the support systems and gaps between the fuel bundles and the guide tubes; the methods used to lump the masses of the fuel bundles and the guide tubes; the methods used to account for the effect of sloshing water on the pool walls; and, the effect of submergence on the mass, the mass distribution and the effective damping of the fuel bundle and the fuel racks.

The design and analysis procedures in accordance with SRP Section 3.8.4, subsection II., are acceptable. The effect on gaps, sloshing water, and increase of effective mass and damping due to submergence in water should be quantified.

When pool walls are utilized to provide lateral restraint at higher elevations, a determination of the flexibility of the pool walls and the capability of the walls to sustain such loads should be provided. If the pool walls are flexible (having a fundamental frequency less than 33 Hertz), the floor response spectra corresponding to the lateral restraint point at the higher elevation are likely to be greater than those at the base of the pool. In such a case using the response spectrum approach, two separate analyses should be performed as indicated below:

(a) A spectrum analysis of the rack system using response spectra corresponding to the highest support elevation provided that there is not significant peak frequency shift between the response spectra at the lower and higher elevations; and

(b) A static analysis of the rack system by subjecting it to the maximum relative support displacement.

The resulting stresses from the two analyses above should be combined by the absolute sum method.

In order to determine the flexibility of the pool wall it is acceptable for the applicant to use equivalent mass and stiffness properties obtained from calculations similar to those described in Ref. 4.1. Should the fundamental frequency of the pool wall model be higher than or equal to 33 Hertz, it may be assumed that the response of the pool wall and the corresponding lateral support to the new rack system are identical to those of the base slab, for which appropriate floor response spectra or ground response spectra may already exist.

(6) Structural Acceptance Criteria

The structural acceptance criteria are those given in the Table 1. When buckling loads are considered in the design, the structural acceptance criteria shall be limited by the requirements of Appendix XVII to Reference 3.1.

For impact loading, the ductility ratios utilized to absorb kinetic energy in the tensile, flexural, compressive, and shearing modes should be quantified. When considering the effects of seismic loads, factors of safety against gross sliding and overturning of racks and rack modulus under all probable service conditions shall be in accordance with SRP Section 3.8.5, subsection II.5. This position on factors of safety against sliding and tilting need not be met provided any one of the following conditions is met:

(a) it can be shown by detailed nonlinear dynamic analyses that the amplitudes of sliding motion are minimal, and impact between adjacent rack modules or between a rack module and the pool walls is prevented provided that the factors of safety against tilting are within the values permitted by SRP Section 3.8.5, subsection II.5.

(b) it can be shown that any sliding and tilting motion will be contained within suitable geometric constraints such as thermal clearances, and that any impact due to the clearances is incorporated.

The fuel pool structure should be designed for the increased loads due to the new and/or expanded high density racks. The fuel pool liner leak tight integrity should be maintained or the functional capability of the fuel pool should be demonstrated.

(7) Materials, Quality Control, and Special Construction Techniques

The materials, quality control procedures, and any special construction techniques should be described. The sequence of installation of the new fuel racks, and a description of the precautions to be taken to prevent damage to the stored fuel during the construction phase should be provided.

If connections between the rack and the pool liner are made by welding, the welder as well as the welding procedure for the welding assembly shall be qualified in accordance with the applicable code.

If spent fuel pool racks are fabricated from aluminum the guidance regarding material properties can be found in References 3.3 and 3.4.[130]

TABLE 1

LOAD COMBINATION	ACCEPTANCE LIMIT
$D + L$	Level A service limits
$D + L + T_0$	
$D + L + T_0 + E$	
$D + L + T_a + E$	Level B service limits
$D + L + T_0 + P_f$	
$D + L + T_a + E'$	Level D service limits
$D + L + F_d$	The functional capability of the fuel racks should be demonstrated

Limit Analysis:

$1.7\ (D + L)$	Appendix XVII, Article[131] 4000 of ASME Code, Section III
$1.3\ (D + L + T_0)$	

$1.7 (D + L + E)$

$1.3 (D + L + E + T_0)$

$1.3 (D + L + E + T_a)$

$1.3 (D + L + T(o) + P_f)$

$1.1 (D + L + T(a) + E')$

Notes:

1. The abbreviations in the table above are those used in subsection II.3.a of this SRP section where each term is defined except for T_a which is defined here as the highest temperature associated with the postulated abnormal design conditions.

2. Deformation limits specified by the Design Specification limits shall be satisfied, and such deformation limits should preclude damage to the fuel assemblies.

3. The provisions of Subsection[132] NF 3231.1 of Reference 3.1 shall be amended by the requirements of paragraphs c.2.3 and 4 of Regulatory Guide 1.124 entitled "Design Limits and Load Combinations for Class 1 Linear-Type Component Supports."

4. F_d is the force caused by the accidental drop of the heaviest load from the maximum possible height and P_f is upward force on the racks caused by postulated struck fuel assembly.

REFERENCES

Regulatory Guides

1.1 1.29 - Seismic Design Classification

1.2 1.60 - Design Response Spectra for Seismic Design of Nuclear Power Plants

1.3 1.61 - Damping Values for Seismic Design of Nuclear Power Plants

1.4 1.76 - Design Basis Tornado for Nuclear Power Plants

1.5 1.92 - Combining Modal Responses and Spatial Components in Seismic Response Analysis

1.6 1.124 - Design Limits and Loading Combinations for Class 1 Linear-Type Components Supports

<u>Standard Review Plan Section</u>

2.1 3.7 - Seismic Design

2.2 3.8.4 - Other Category I Structures

<u>Industry Codes and Standards</u>

3.1 American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section III, Division 1.

3.2 American National Standards Institute, N210-76,[133] "Requirements for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Plants, Design."[134]

3.3 American Society of Civil Engineers, Suggested Specification for Structures of Aluminum Alloys 6061-T6 and 6067-T6.

3.4 The Aluminum Association, Specification for Aluminum Structures

<u>Other</u>

4.1[135] ~~Briggs~~Biggs,[136] John M., "Introduction to Structural Dynamics," McGraw-Hill Book Co., New York, 1964.

APPENDIX E TO SRP SECTION 3.8.4

STAFF POSITION ON STEEL EMBEDMENTS[137]

Introduction

The American Concrete Institute (ACI) 349 Code has been developed by the professional community for the design of seismic Category I structures. The staff reviewed Appendix B to ACI 349-85, "Code Requirements for Nuclear Safety Related Concrete Structures," and foreign and domestic test data for anchor bolts. On the basis of that review, the staff has taken exceptions to Appendix B to the ACI 349 Code as detailed below. This position has been developed as an aid for the review of applications. The staff's primary concerns regarding Appendix B to the ACI 349 Code are discussed below and exceptions to the use of Appendix B are noted.

The staff's primary concern with Appendix B to the ACI 349 Code is the use of a basic assumption of the 45-degree concrete-failure cone. This assumption may have been chosen for convenience. However, tests have not confirmed this assumption even for single anchors. The assumption becomes even less conservative when an anchor is located near the free edge of the concrete or when anchors are closely spaced.

Appendix B to the ACI 349 Code is deficient because it has no provisions for reduced anchor strength when the anchor is located in cracked concrete, such as in the tension zone of a concrete slab.

STAFF'S EXCEPTIONS TO APPENDIX B TO THE ACI 349 CODE

Section B.4.2 - Tension and Figures B.4.1 and B.4.2

In this section and the figures, ACI specifies that the tensile strength of concrete for any anchorage can be calculated by a 45-degree failure-cone theory. The staff disseminated the German test data questioning the validity of the 45-degree failure-cone theory to licensees, architect-engineers, bolt manufacturers, and the code committee members when it met with them. The data showed that the actual failure cone was about 35 degrees and the use of the 45-degree cone theory could be unconservative for anchorages of deep embedment, and for the anchorage of groups of bolts. The code committee, having done some research of its own, recently agreed with the staff's finding. The code committee is now revising this section. In the meantime, the staff position on issues related to this section is to ensure adoption of design approaches consistent with the test data through case-by-case review.

Section B.5.1.1 - Tension

In this section, ACI states a criterion for ductile anchors. The criterion is that the design pullout strength (force) of the concrete as determined in Section B.4.2 exceeds the minimum specified tensile strength (force) of the steel anchor. Any anchor that meets this criterion is qualified as a ductile anchor and, thus, a low safety factor can be used. The staff believes that the criterion is deficient in two areas: (1) the design pullout strength of the concrete, so calculated, is usually higher than the actual strength, as has been stated in Section B.4.2 above and (2) anchor steel characteristics are not taken into consideration. For example, Drillco Maxi-Bolt Devices, Ltd. claims that its anchors are ductile anchors and, thus, can use a low safety factor. The strength of the Maxi-Bolt is based on the yield strength of the anchor steel, which is 724 MPa (105 ksi). The embedment length of the anchor, which is used to determine the pullout strength of the concrete, is based on the minimum specified tensile strength of the anchor steel of 862 MPa (125 ksi). The staff believes that the 19 percent margin (125/105) for the embedment length calculation is insufficient considering the variability of parameters affecting the concrete cone strength. The staff also questions the energy absorption capability (deformation capability after yield) of such a high-strength anchor steel. Therefore, in addition to the position taken with regard to Section B.4.2 above, the staff will review vendor- or manufacturer-specific anchor bolt behaviors to determine the acceptable design margins between anchor bolt strengths and their corresponding pullout strengths based on concrete cones.

Section B.5.1.1(a) - Lateral Bursting Concrete Strength

This section states that the lateral bursting concrete strength is determined by the 45-degree concrete-failure-cone assumption. This assumption has not been confirmed by tests and the code committee is revising the assumption. The staff believes that the lateral bursting concrete strength determination also needs to be revised. To determine if adequate reinforcement against lateral bursting force needs to be determined on a case-by-case basis, the staff will review the following against test data: (1) the lateral bursting concrete strength provided by the concrete cover around anchor bolts and (2) the lateral bursting force created by the pulling of anchor bolts.

Section B.5.1.2.1 - Anchor, Studs, or Bars

This section states that the concrete resistance for shear can be determined by a 45-degree half-cone to the concrete free surface from the centerline of the anchor at the shearing surface. Since the assumption for 45-degree concrete-failure cone for tension has not been proved, the staff believes that the use of the 45-degree half-cone for shear should be reexamined. In the meantime, the staff will review the adequacy of shear capacity calculations of concrete cones on a case-by-case basis with emphasis on methodology verification through vendor-specific test data.

Section B.5.1.2.2(c) - Shear Lugs

In this section, ACI states that the concrete resistance for each shear lug in the direction of a free edge shall be determined based on the 45-degree half-cone assumption to the concrete free surface from the bearing edge of the shear lug. This is the same assumption as used in Section B.5.1.2.1, and the staff has the same comment as stated there. Therefore, the staff position related to the design of shear lugs is to do case-by-case reviews. The staff review will emphasize methodology verification through specific test data.

Section B.7.2 - Alternative Design Requirements for Expansion Anchors

In this section, ACI states that the design strength of expansion anchors shall be 0.33 times the average tension and shear test failure loads, which provides a safety factor of 3 against anchor failure. The staff position on safety factor for design against anchor failure is 4 for wedge anchors and 5 for shell anchors unless a lower safety factor can be supported by vendor-specific test data.

Section B.7.2 - Anchors in Tension Zone of Supporting Concrete

When anchors are located within a tensile zone of supporting concrete, the anchor capacity reduction due to concrete cracking shall be accounted for in the anchor design.

REFERENCES

1. Final Safety Evaluation Report Related to the Certification of the Advanced Boiling Water Reactor Design, Appendix F, NUREG-1503, Vol. 2, July 1994.

2. Final Safety Evaluation Report Related to the Certification of the System 80+ Design, Appendix 3A, NUREG-1462, August 1994.

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Section B.5.1.2.2(c) - Shear Lugs

In this section, ACI states that the concrete resistance for each shear lug in the direction of a free edge shall be determined based on the 45-degree half-cone assumption to the concrete free surface from the bearing edge of the shear lug. This is the same assumption as used in Section B.5.1.2.1, and the staff has the same comment as stated there. Therefore, the staff position related to the design of shear lugs is to do case-by-case reviews. The staff review will emphasize methodology verification through specific test data.

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In this section, ACI states that the design strength of expansion anchors shall be 0.33 times the average tension and shear test failure loads, which provides a safety factor of 3 against anchor failure. The staff position on safety factor for design against anchor failure is 4 for wedge anchors and 5 for shell anchors unless a lower safety factor can be supported by vendor-specific test data.

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When anchors are located within a tensile zone of supporting concrete, the anchor capacity reduction due to concrete cracking shall be accounted for in the anchor design.

REFERENCES

1. Final Safety Evaluation Report Related to the Certification of the Advanced Boiling Water Reactor Design, Appendix F, NUREG-1503, Vol. 2, July 1994.

2. Final Safety Evaluation Report Related to the Certification of the System 80+ Design, Appendix 3A, NUREG-1462, August 1994.

APPENDIX F TO SRP SECTION 3.8.4

STAFF POSITIONS AND TECHNICAL BASES ON THE
USE OF STANDARD ANSI/AISC N690-1984
NUCLEAR FACILITIES: STEEL-RELATED
STRUCTURES[138]

The use of ANSI/AISC Standard N690-1984 for the design, fabrication, and erection of safety-related structures is acceptable to the staff when supplemented by the following staff positions and technical bases.

Staff Positions

(1) In Section Q1.0.2, the definition of secondary stress should apply to stresses developed by temperature loading only.

(2) Add the following notes to Section Q1.3.6:

"When any load reduces the effects of other loads, the corresponding coefficient for that load should be taken as 0.9, if it can be demonstrated that the load is always present or occurs simultaneously with other loads. Otherwise, the coefficient for that load should be taken as zero."

"Where the structural effects of differential settlement are present, they should be included with the dead load 'D'."

"For structures or structural components subjected to hydrodynamic loads resulting from LOCA and/or safety relief valve actuation, the consideration of such loads should be as indicated in the Appendix to SRP Section 3.8.1. Any fluid structure interaction associated with these hydrodynamic loads and those from the postulated earthquake(s) should be taken into account."

(3) The stress limit coefficients (SLCs) for compression in Table Q1.5.7.1 should be as follows:

1.3 instead of 1.5 [stated in footnote (c)] in load combinations 2, 5, and 6.

1.4 instead of 1.6 in load combinations 7, 8, and 9.

1.6 instead of 1.7 in load combination 11.

(4) Add the following note to Section Q1.5.8:

"For constrained (rotation and/or displacement) members supporting safety-related structures, systems, or components the stresses under load combinations 9, 10, and 11 should be limited to those allowed in Table Q1.5.7.1 as modified by provision 3 above. Ductility factors of Table Q.5.8.1 (or provision 5 below) should not be used in these cases."

(5) For ductility factors 'μ' in Sections Q1.5.7.2 and Q1.5.8, substitute provisions of Appendix A, II.2 of SRP Section 3.5.3 in lieu of Table Q1.5.8.1.

(6) In load combination 9 of Section Q2.1, the load factor applied to load P_a should be 1.5/1.1≈1.37, instead of 1.25.

(7) Sections Q1.24 and Q1.25.10 should be supplemented with the following requirements regarding painting of structural steel:

(a) Shop painting to be in accordance with Section M3 of LRFD specifications ("Load and Resistance Factor Design (LRFD) Specification for Structural, Steel Buildings and Its Commentary," American Institute of Steel Construction, Chicago, 1986).

(b) All exposed areas after installation to be field painted (or coated) in accordance with the applicable portion of Section M3 of LRFD specifications.

(c) The QA requirements for painting (or coating) of structural steel to be in accordance with ANSI N101.4 ("Quality Assurance for Protective Coatings Applied to Nuclear Facilities," American Institute for Chemical Engineers, New York, 1972), as endorsed by RG 1.54, "Quality Assurance Requirements for Protective Coatings Applied to Water Cooled Nuclear Power Plants."

Technical Bases

(1) The standard defines the "secondary stress" as: "any normal stress or shear stress developed by the constraint of adjacent material or by self-constraint of the structure. The basic characteristic of a secondary stress is that it is self-limiting due to deformation-limited effects." This definition has been interpreted by some to be applicable to the stresses generated by mechanical (i.e., non-thermal) loads at the structural discontinuities. The position in Section I of this Appendix clarifies the staff's interpretation.

(2) These notes provide guidance to the users regarding consideration of additional load effects in designing steel structures. The notes are parts of SRP Sections 3.8.3 and 3.8.4.

(3) The research done in the last 12 years on the strength and stability of compression members shows that the base curve (SSRC curve in Figure F.1) used in arriving at the SLCs in SRP Sections 3.8.3, and 3.8.4, and in the standard does not reflect the results of the available test data. In developing the American Institute of Steel Construction (AISC) building specification based on the load and resistance factor design (LRFD) concept, the AISC changed the formulation for compression members to reflect the results of the test data. The LRFD curve (with ρ=1.0) is also shown in Figure F.1.

Based on the test data, this curve has the minimum reliability index, β (defined as the ratio of ln (R_m/Q_m) to $(V_r^2 + V_Q^2)^{1/2}$; where R_m = median value of resistance, Q_m = median value of load; and, V_r, and V_q are the corresponding coefficients of variation), of 2.6 (LRFD Specification for Structural Steel Buildings and Its Commentary, Published by AISC, Chicago, September 1, 1986). The LRFD specification requires ρ = 0.85 in establishing the resistance of compression members.

Figure F.1 of this Appendix shows the curves reflecting the SLCs of 1.0, 1.4, 1.5, 1.6, and 1.7 as applied to the stresses specified for allowable stress design of the AISC. Based on the comparison with the LRFD curve (ρ=1.0), the following SLCs are recommended in the interim position:

SLC of 1.6 (ρ≈0.95) for load combinations 10 and 11. This is reasonable for load combinations containing the effects of the two low-probability events, that is, safe-shutdown earthquake (SSE) and loss-of-coolant accident (LOCA).

SLC of 1.4 (ρ≈0.84) for load combinations 7, 8, and 9. This is appropriate for combinations containing the effects of a single, low-probability event, that is, SSE, tornado, or LOCA.

SLC of 1.3 in load combinations 2, 5, and 6 is recommended when the secondary stresses due to T_o are included in the load combinations. This is consistent with the current position of allowing higher stresses under the effects of operating temperature.

(4) Neither the Standard Review Plan (SRPs) nor the Standard offer any guidance regarding the tolerable deformation of the constrained steel members when they are subjected to temperature growth under sustained T_a or other LOCA loads. Statistically meaningful test data simulating the inelastic behavior of such constrained members under representative load combinations (including T_a and E_s are not available. This provision ensures against the instability condition arising from the effects of T_a or other LOCA loads under load combinations 9, 10, and 11.

(5) The ductility factors provided in Table Q1.5.8.1 are either more liberal than those in Appendix A of SRP Section 3.5.3 (e.g., μ for compression members), or involve some inconsistencies in definitions and interpretation of the formulae (e.g., "formulae" in 2.D of the table) given in the table. Therefore, until sufficient test-based justification for ductility factors listed in Table Q1.5.8.1 is provided, the staff position as stated in the appendix is recommended for use.

(6) This provision makes the load combination consistent with that in the SRP.

(7) Additional provision regarding painting of structural steel is provided.

REFERENCES

1. Final Safety Evaluation Report Related to the Certification of the Advanced Boiling Water Reactor Design, Appendix G, NUREG-1503, Vol. 2, July 1994.

2. Final Safety Evaluation Report Related to the Certification of the System N80+ Design, Appendix 3B, NUREG-1462, August 1994.

3. "Load and Resistance Factor Design (LRFD) Specification for Structural Steel Buildings," American Institute of Steel Construction, Chicago, September 1, 1986.

4. "Quality Assurance for Protective Coatings Applied to Nuclear Facilities," American Institute for Chemical Engineers, New York, 1972.

5. ANSI/AISC N690, "Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities," American Institute of Steel Construction, New York, 1984.

APPENDIX G TO SRP SECTION 3.8.4

DYNAMIC LATERAL SOIL PRESSURES ON EARTH RETAINING WALLS AND EMBEDDED WALLS OF NUCLEAR POWER PLANT STRUCTURES[139]

INTRODUCTION

In the design of earth retaining walls and embedded exterior walls of nuclear power plant structures, it is important to include the loads due to seismically induced lateral soil pressures. Standard Review Plan (SRP) Section 2.5.4, which deals with the stability of subsurface materials and foundations, does not provide specific review criteria regarding acceptable procedures to determine the dynamic lateral soil pressures. However, SRP Section 2.5.4 contains a generic statement that the applicant should satisfy the requirements of applicable codes and standards in designing the structures, systems, and components (SSCs) (in accordance with 10 CFR 50.55a). In addition, SRP Section 2.5.4 states that state-of-the-art methods are to be used to design the structures. Section 3.5.3 of American Society of Civil Engineers (ASCE) 4-86 ("Seismic Analysis of Safety Related Nuclear Structures and Commentary on Seismic Analysis of Safety Related Nuclear Structures," New York, NY, 1986), which is currently being revised by ASCE, identifies certain analytical methods to be used to establish dynamic lateral soil pressures for the design of retaining walls or structures founded below grade surface (J. H. Wood, "Earthquake-Induced Soil Pressures on Structures," Report No. EERL 73-05, Earthquake Engineering Research Laboratory, California Institute of Technology, Pasadena, CA, August 1973, and H. B. Seed and R. V. Whitman, "Design of Earth Retaining Structures for Dynamic Loads," Proceedings of the ASCE Specialty Conference on lateral Stresses in the Ground and Design of Earth Retaining Structures, Cornell University, Ithaca, NY, 1970). These methods are based on the original analysis of this problem by Mononobe and Okabe (M-O) in the 1920s (ASCE 4-86) (Ref. 4, 5, 6, and 7).

Seed and Whitman (1970) presented a classical state-of-the-art report at the ASCE Specialty Conference on Lateral Stresses in the Ground and Design of Earth-Retaining Structures held in 1970. They presented data to show that seismic lateral pressure coefficients for cohesionless backfills computed by the M-O method agreed reasonably well with the values developed in small-scale (model) tests. Subsequently, several researchers made significant contributions to this important subject area: (1) R. V. Whitman, "Seismic Design and Behavior of Gravity Retaining Walls," Proceedings of the ASCE Conference on Design and Performance of Earth Retaining Structures, Cornell University, Ithaca, NY, 1990; (2) R. Richards, Jr. and D. G. Elms, "Seismic Behavior of Gravity Retaining Walls," ASCE Journal, GT Division, Vol. 105, April 1979; (3) R. V. Whitman, "Seismic Design of Earth Retaining Structures," Proceedings of the Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and soil Dynamics, St. Louis, MO, March 11 through 15, 1991; (4) C. Y. Chang et al., "Analysis of Dynamic lateral Soil Pressures Recorded on Lotung Reactor Containment Model Structure," Proceedings of the 4th U.S. National Conference on Earthquake Engineering, Palm Springs, CA, May 20 through 24, 1990; and (5) C. Soydemir, "Seismic Design of Rigid Underground Walls in New England," Proceedings of the 2nd International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, MO, March 11 through 15, 1991. In November 1992, the U.S. Army Corps of

Engineers, acting as a consultant for the U.S. Naval Civil Engineering Laboratory, published a comprehensive technical report (with about 30 sample problems and solutions) on the seismic design of waterfront retaining structures (U.S. Army Corps of Engineers Technical Report ITL-92-11, "The Seismic Design of Waterfront Retaining Structures," Vicksburg, MS, November 1992). This report (prepared with input from a team of experts in the United States and Canada) summarizes the procedures recommended for computing dynamic lateral soil pressures and grouping them according to the expected displacement of the backfill and wall during seismic events. The Department of Energy is currently engaged n research and development work related to the area of dynamic lateral soil pressures. This brief summary of work done in the area of lateral pressures is not, by any means, complete; however, it gives a good indication of the apparently large uncertainties that appear to be unresolved in this area.

Bechtel Power Corporation, a consultant for General Electric for the ABWR standardized design of seismic Category I structures, has calculated the dynamic lateral soil pressures on retaining walls and embedded exterior walls of structures, using the M-O method mentioned previously. In a section of Bechtel's proprietary report (Bechtel Power Corporation Proprietary Design Guide, C-2.44, Revision 0, August 1980 (version of Bechtel topical Report, BC-TOP-4A, Revision 3, "Seismic Analysis of Structures and Equipment for Nuclear Power Plants," San Francisco, CA, November 1974), it is stated that the M-O method was modified, where necessary, by procedures suggested by Wood in 1973 (EERL 73-05), and by some other researchers. Judging from the large amount of work reported in this area after 1979 (Whitman 1990, Richards and Elms 1979, Whitman 1991, C. Y. Chang et al. 1990, and Soydemir 1991, it appears that the procedures recommended in Bechtel's design guide mentioned above may not fully reflect the advances made in the state of the art in this area since 1979. The objective of this paper is to review as many significant research papers available in the literature as possible, and comment on the appropriateness of Bechtel's procedures for calculating dynamic lateral soil pressures, for the staff guidance in the review of the advanced light water reactor (ALWR), including ABWR, standard design.

REVIEW OF CURRENT ANALYTICAL PROCEDURES

Mononobe and Okabe (ASCE 4-86) proposed a somewhat complicated equation to calculate the dynamic lateral soil pressures due to both horizontal and vertical earthquake accelerations. Their method, developed for dry cohesionless backfill materials, was essentially based on the classical coulomb's theory of earth pressures with the following assumptions:

(1) The wall yields sufficiently to produce minimum active earth pressures.

(2) A soil wedge behind the wall is at the point of incipient failure and the maximum soil shear strength is mobilized along the potential sliding surface, which passes through the toe of the wall.

(3) The soil wedge behind the wall acts as a rigid body so that seismic accelerations may be considered uniform throughout the mass.

Seed and Whitman (1970) stated that Mononobe and Okabe apparently assumed that the total pressure computed by their analytical approach would act on the wall at the same position as the initial static pressure, that is, at one-third the height of the wall above the base. Other researchers, however, subsequently found that this assumption was not correct and that the dynamic lateral force increment acted at about the middle height of the wall (EERL 73-05 and Whitman 1970). In view of the complex nature of the M-O equation that gives the total dynamic lateral pressure, Seed and Whitman also proposed a simplification of the M-O method to calculate the dynamic active lateral force increment. Seed and Whitman (1970) cited the work by Kapila, in 1962, on the determination of both active and passive lateral pressures by the M-O method, utilizing graphical construction.

While the M-O method was developed for yielding retaining walls, Wood (EERL 73-05) and Seed and Whitman (1970) found a solution for nonyielding walls, using elastic theory and assuming that material properties are constant with depth. Wood's solution predicted that the dynamic lateral force increment would act at about 0.63 times the height of the wall, which corresponded approximately to a parabolic distribution of earth pressure unlike M-O's inverted triangular distribution. Wood's theoretical work was corroborated by experimental shake table tests conducted by others who found that the measured lateral pressures on nonyielding walls exceeded those predicted by the M-O method by a factor of 2 to 3 (Whitman 1990). Finite element analyses in which the soil modulus increased with depth resulted in 5 percent to 15 percent smaller dynamic lateral pressures, with the resultant acting closer to 0.5 times the height of the wall Whitman 1990).

According to Whitman (1990), Richards and Elms made a major advance in the area of dynamic lateral pressures by formulating a displacement-oriented solution that used the concept of allowable permanent movement of the gravity retaining walls (Soydemir 1991). Their approach, called the displacement-controlled method, differs from that of the M-O method with is strength controlled. Whereas some traditional designers using the M-O method are reported to have assumed less than the maximum design earthquake, the displacement-controlled approach of Richards and Elms permits the selection of a proper design acceleration coefficient (Whitman 1990). Further, their method, based on Newmark's sliding block analogy and retaining the M-O equation, permits an evaluation of permanent displacement of retaining walls following an earthquake (Whitman 1991).

On the basis of a review of several researchers in this area, Whitman concluded that model test results have given continuing support for the use of the M-O equation for the design of relatively simple walls, 9.14 m (30 ft) or less in height; however, for higher walls and nonyielding walls, he recommends more careful analysis (Whitman 1990). Regarding basement walls, Whitman, in his second state-of-the-art paper (Whitman 1991), stated that the use of Wood's theory (EERL 73-05) for nonyielding walls may seem logical, if the basement rests directly on hard rock and if the outside walls of the basement are well braced by floors. He further states that actual peak acceleration should be used if any yielding or cracking of the walls is to be avoided. These requirements, according to Whitman (1991), can lead to quite large lateral soil pressures.

Chang et al. (1990) described a study that evaluated the uncertainties of several analytical solutions by comparing the computed and recorded dynamic lateral soil pressures on the embedded wall of the Lotung, Taiwan 1/4-scale model structure during several moderate earthquakes. In this study, a 1/4-scale reactor containment model structure was embedded at a depth of 4.57 m (15 ft) below the ground surface. The analysis of recorded data showed that the magnitude of dynamic lateral soil pressures was significantly lower than that predicted by published elastic solutions (ASCE 4-86 and EERL 73-50). The recorded dynamic lateral pressure increments were similar to, or lower than, those calculated by the M-O method. On the basis of the results of this study, Whitman concluded that it may suffice to use the M-O equation together with the actual expected peak acceleration Whitman 1991.

Although the above conclusion may be generally true, it appears that Whitman's conclusion did not cover certain additional field data and discussions provided by Chang et al. (1990). These relate to (1) the effect of variation of the backfill shear modulus with depth and (2) the effect of the rocking motion on the dynamic lateral pressure distribution, which were measured at the Lotung site. The soil shear modulus is generally smaller at the ground surface because of low confining pressure and gradually increases with depth, contrary to the constant modulus assumption in elastic solutions. Probably because of this factor, the recorded dynamic earth pressures were substantially smaller than those given by the elastic solutions (Chang et al. 1990). On the basis of a detailed study of the Lotung site data, Chang et al. (1990) have concluded that the dynamic earth pressures acting on an embedded symmetrical structure are related primarily to soil-structure interaction (SSI) and that this phenomenon is different from that of a yielding retaining wall being acted upon by an active earth pressure. Thus, the concept of limiting equilibrium used in the M-O method is not strictly applicable to the dynamic earth pressures on embedded structures.

Soydemir (1991) has also recommended caution in using the M-O method indiscriminately. He points out that the M-O method is being used without checking whether the retaining structures yield or not, and whether the conditions assumed in the M-O analysis are satisfied. Soydemir states that, even though the M-O equation for active earth pressure conditions is quite appropriate for yielding walls, it may underestimate the dynamic lateral pressures acting on rigid, nonyielding earth retaining walls or structures.

Section 4.5 of Bechtel Design Guide C-2.44 (1980) states that the M-O method is used to evaluate the seismically induced lateral soil pressures in the earthquake-resistant design of both the retaining walls and the embedded portions of exterior walls of nuclear power plant structures. The Design Guide further states that, when the wall does not experience sliding or rotation, the elastic solution (EERL 73-05) becomes more appropriate. In such cases, in addition to the "at rest" static pressures, all the resulting dynamic forces are to be increased by a factor of 2 for consideration of such nonyielding conditions (e.g., the embedded walls of massive structures.) The report states that the value of 2 is based on the findings of Wood (EERL 73-05) and also on the fact that "at rest" pressures are about twice the active pressures. Since the factor 2 is for an infinitely long backfill, the Design Guide says that the appropriate elastic solution can be used for shorter lengths of backfills. Section 4.5 of the Design Guide is silent about the seismic lateral pressures due to submerged backfill, for which procedures are available in the literature (H. Matsuzawa et al., "Dynamic Soil and Water Pressures on Submerged Soils," ASCE Journal of Geotechnical Engineering, Vol. 111, No. 10, October 1985).

CONCLUSION AND RECOMMENDATIONS

On the basis of a review of the papers and reports cited above and also conversations with experienced engineers working in this area at universities, industry, and Government agencies, the staff believes that the calculation procedures suggested in Bechtel Design Guide C-2.44 (1980) are generally adequate for walls with shallow embedment. However, the Design Guide does not specifically address several factors, such as the effect of depth of embedment of exterior walls of nuclear power plant structures which have embedments ranging from 12.2 m (40 ft) to 25.9 m (85 ft), in the case of ABWR.

The results of reviewing those papers and reports can be summarized as follows:

(1) In determining the dynamic lateral soil pressures, it is necessary to distinguish three different types of structures, each of which may require a distinct analysis and evaluation. They are (a) gravity retaining walls and sheetpile walls, etc., with level or sloping backfill starting t the same elevation as the top of the retaining wall; (b) basement walls in buildings with the superstructure above the ground (e.g., embedded walls of nuclear power plant structures); and (c) completely buried underground structures (e.g., tunnels, underground tanks).

(2) For rigid walls with shallow embedment, it seems appropriate to use the M-O method using the peak ground acceleration coefficient.

(3) For deeply embedded basement walls with a massive superstructure above ground, which may experience rocking components of motion, and for rigid gravity walls, which may undergo rotational displacements about the vertical axis, the use of the M-O method does not seem appropriate. For such cases, the procedures recommended in Bechtel Design Guide C-2.44 (1980) need to be modified, in view of the extensive amount of more recent work done in this area. Proper consideration should be given to the actual conditions (e.g., variations of soil properties and seismic accelerations with depth, flexibility and expected deformations of embedded walls) while determining the appropriate method to calculate the lateral soil pressures, as the U.S. Army report (ITL-92-11) has attempted to do. In such complex cases, the lateral soil pressures derived from the results of an SSI analysis may be used in conjunction with the pressures predicted by the M-O method to determine a range of dynamic lateral pressures that could be expected to act on the embedded walls. These results may also be compared, as a check, with the lateral soil pressures that could be estimated by using the Uniform Building Code provisions for the base shear. In case an applicant wishes to use the elastic solution proposed by Wood (EERL 73-05), a case-by-case justification for the factor 2 for nonyielding walls mentioned in Bechtel Design Guide C-2.44 (1980) must be provided by the applicant.

REFERENCES

1. American Society of Civil Engineers (ASCE), 4-86, Section 3.5.3, "Seismic Analysis of Safety Related Nuclear Structures and Commentary on Seismic Analysis of Safety Related Nuclear Structures," New York, NY, 1986.

2. J. H. Wood, "Earthquake-Induced Soil Pressures on Structures," Report No. EERL 73-05, Earthquake Engineering Research Laboratory, California Institute of Technology, Pasadena, CA, August 1973.

3. H. B. Seed and R. V. Whitman, "Design of Earth Retaining Structures for Dynamic Loads," Proceedings of the ASCE Specialty Conference on Lateral Stresses in the Ground and Design of Earth Retaining Structures, Cornell University, Ithaca, NY, 1970.

4. N. Mononobe, "Design of Aseismic Gravity Wall," Report of Kanto Earthquake Damages of 1923, Journal of JSCE, Vol. 3, 1925.

5. S. Okabe, "General Theory of Earth Pressure and Seismic Stability of Retaining Wall and Dam," Journal of JSCE, Vol. 12, No. 1, 1924.

6. N. Mononobe and H. Matuo, "Experimental Investigation of Lateral Earth Pressure During Earthquakes," Bulletin of Earthquake Research Institute, Tokyo University, Vol. X, Part 4, 1932.

7. N. Mononobe and H. Matuo, "On Determination of Earth Pressure During Earthquakes," World Engineering Congress, Tokyo, 1929, Paper No. 388.

8. R. V. Whitman, "Seismic Design and Behavior of Gravity Retaining Walls," Proceedings of the ASCE Conference on Design and Performance of Earth Retaining Structures, Cornell University, Ithaca, NY, 1990.

9. R. Richards, Jr., and D. G. Elms, "Seismic Behavior of Gravity Retaining Walls," ASCE Journal, GT Division, Vol. 105, April 1979.

10. R. V. Whitman, "Seismic Design of Earth Retaining Structures," Proceedings of the Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, MO, March 11 through 15, 1991.

11. C. Y. Chang, et al., "Analysis of Dynamic lateral Soil Pressures Recorded on Lotung Reactor Containment Model Structure," Proceedings of the 4th U.S. National Conference on Earthquake Engineering, Palm Springs, CA, May 20 through 24, 1990.

12. C. Soydemir, "Seismic Design of Rigid Underground Walls in New England," Proceedings of the 2nd International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, MO, March 11 through 15, 1991.

13. U.S. Army Corps of Engineers Technical Report ITL-92-11, "The Seismic Design of Waterfront Retaining Structures," Vicksburg, MS, November 1992

14. Final Safety Evaluation Report Related to the Certification of the Advanced Boiling Water Reactor Design, Appendix H, NUREG-1503, Vol. 2, July 1994.

15. "Seismic Analysis of Structures and Equipment for Nuclear Power Plants," Design Guide C-2.44, Bechtel Power Corp., August 1980, Rev. 0, (Proprietary).

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Attachment A - Proposed Changes in Order of Occurrence

Item numbers in the following table correspond to superscript numbers in the redline/strikeout copy of the draft SRP section.

Item	Source	Description
1.	Current PRB name and abbreviation	Changed PRB to Civil Engineering and Geosciences Branch (ECGB)
2.	Editorial	Provided "LOCA" as initialism for "loss-of-coolant accident" and eliminated unnecessary phrase.
3.	Editorial	Provided "SRP" as initialism for "Standard Review Plan."
4.	Integrated Impact No. 771	Expanded description of distant, safety-related structures to reflect the requirements of 10 CFR Part 100 Appendix A, V(d)(4).
5.	Editorial	Changed "is" to "are" for number agreement.
6.	SRP-UDP format item	Deleted unnecessary callout for "(Ref. 1)" and provided actual title of document referenced.
7.	Editorial	Provided cross references to new appendix.
8.	Integrated Impact No.775	Replaced the AISC Specification with the ANSI/AISC Specifications to reflect current PRB design criteria.
9.	SRP-UDP format item	Deleted unnecessary reference callout "(Ref. 3)."
10.	Integrated Impacts Nos. 769, 774, and 775	Added reference to Appendices E, F, and G to reflect the current PRB positions on ACI 349 and ANSI/AISC N690.
11.	NUREG-1503 and NUREG-1462	Added reference to Appendix E, "Staff Position on Steel Embedments," to reflect current PRB design criteria.
12.	NUREG-1462 and NUREG-1503	Added reference to Appendix F, "Staff Position and Technical Bases on the Use of Standard ANSI/AISC N690-1984 Nuclear Facilities: Steel Safety-Related Structures," to reflect current PRB design criteria.
13.	NUREG-1462 and NUREG-1503	Added reference to Appendix G, "Dynamic Lateral Soil Pressures on Earth Retaining Walls and Embedded Walls of Nuclear Power Plant Structures," to reflect current PRB design criteria.
14.	Editorial	Deleted unnecessary repetition of "specified."
15.	Editorial	Clarified a reference to an SRP subsection.
16.	SRP-UDP format item	Added "Review Interfaces" to AREAS OF REVIEW and organized in numbered paragraph form to describe how ECGB reviews structures other than the containment and how other branches support the ECGB effort.

Item	Source	Description
17.	Current PRB abbreviation	Changed PRB to ECGB.
18.	SRP-UDP format item	Provided number for technical rationale item.
19.	Current SRB abbreviation	Changed to reflect current EMEB responsibility for SRP Sections 3.2.1 and 3.2.2.
20.	Current PRB abbreviation	Changed PRB to ECGB.
21.	SRP-UDP format item	Provided number for technical rationale item.
22.	SRP-UDP format item	Changed to reflect of Plant Systems Branch (SPLB) responsibility for SRP Section 3.6.1.
23.	Current PRB abbreviation	Changed PRB to ECGB.
24.	Current review branch abbreviation	Changed review interface branch to Plant Systems Branch abbreviation (SPLB).
25.	SRP-UDP format item	Provided number for technical rationale item.
26.	SRP-UDP format item	Changed to reflect SCSB responsibility for SRP Section 6.2.1.
27.	Current PRB abbreviation	Changed PRB to ECGB.
28.	SRP-UDP format item	Changed review interface branch to SCSB.
29.	SRP-UDP format item	Provided number for technical rationale item.
30.	SRP-UDP format item	Changed to reflect Quality Assurance and Maintenance Branch responsibility for review of SRP Chapter 17.
31.	Editorial	Changed "SRP Section 17.0" to "SRP Chapter 17" for clarity.
32.	Integrated Impact 773.	Incorporates a review interface with SRP Section 3.6.3 for review of Leak-Before-Break.
33.	Editorial	Simplified for clarity and readability.
34.	SRP-UDP format item	Changed PRB to ECGB.
35.	Editorial	Provided "GDC 1" as an initialism for "General Design Criterion 1."
36.	Editorial	Provided "GDC 2" as an initialism for "General Design Criterion 2."
37.	Editorial	Provided "GDC 4" as an initialism for "General Design Criterion 4."
38.	Editorial	Provided "GDC 5" as an initialism for "General Design Criterion 5."

Item	Source	Description
39.	Editorial	Changed "GDC" to "General Design Criteria" to accommodate plural usage, and made minor changes for clarity.
40.	SRP-UDP format item	Added "Regulatory Guide 1.70."
41.	Integrated Impacts Nos. 650, 769, and 774	Added note regarding Appendix E and RG 1.142 to reflect current design criteria acceptable to the staff.
42.	Editorial	Updated title for standard.
43.	Integrated Impact No. 772	Deleted reference to Regulatory Guides 1.10, 1.15, and 1.55 to reflect the provisions of RG 1.136.
44.	Integrated Impact No. 777	Added provisions for considering dynamic effects of lateral soil pressure.
45.	Editorial	Replace "safe shutdown earthquake" with "SSE".
46.	Editorial	Changed for clarity and readability.
47.	Editorial	The load combination equation in the original SRP contained erroneously the SSE load, "E'." Research was performed by the INEL and concluded that it should have been the OBE, "E" rather than SSE.
48.	Editorial	Added subsection/paragraph reference for clarity.
49.	Editorial	Added subsection/paragraph reference for clarity, struck extra "and" and corrected punctuation.
50.	Integrated Impact No. 775	Replaced the AISC Specification with the ANSI/AISC N690 Specification to reflect current design criteria.
51.	Integrated Impact No. 775	Replaced the AISC Specification with the ANSI/AISC N690 Specification to reflect current design criteria.
52.	Editorial	Added subsection/paragraph number for clarity.
53.	Editorial	Added subsection/paragraph number for clarity.
54.	SRP-UDP format item	Deleted reference number.
55.	Integrated Impacts Nos. 650, 769, and 774.	Referenced RG 1.142 and Appendix E to reflect current design criteria.
56.	Integrated Impact No. 775	Replaced AISC Specification with the ANSI/AISC N690 Specification to reflect current design criteria.
57.	SRP-UDP format item	Deleted reference number.
58.	Integrated Impact No. 776	Added design criteria pertaining to dynamic lateral soil pressures on earth retaining walls to reflect current staff position.
59.	SRP-UDP format item	Added reference to Appendix A.
60.	Editorial	Added "the" for readability.

Item	Source	Description
61.	SRP-UDP format item	Deleted unnecessary callout for "(Ref. 3)."
62.	SRP-UDP format item	Deleted unnecessary callout for "(Ref. 1)."
63.	SRP-UDP format item	Deleted unnecessary callout for "(Ref. 3)." Added "ANSI/AISC N690-1984."
64.	Integrated Impact No. 775	Replaced the AISC Specification with ANSI/AISC N690 to reflect current design criteria.
65.	SRP-UDP format item	Added "Technical Rationale" to ACCEPTANCE CRITERIA and organized in numbered paragraph form to describe the bases for referencing the GDC and 10 CFR 50.55a.
66.	SRP-UDP format item	Added lead-in sentence for "Technical Rationale."
67.	SRP-UDP format item	Added technical rationale for 10 CFR 50.55(a).
68.	SRP-UDP format item	Added technical rationale for GDC 1.
69.	SRP-UDP format item	Added technical rationale for GDC 2.
70.	SRP-UDP format item	Added technical rationale for GDC 4.
71.	SRP-UDP format item	Added technical rationale for GDC 5.
72.	SRP-UDP format item	Added technical rationale for 10 CFR Part 50, Appendix B.
73.	SRP-UDP format item	Deleted "Standard Format" and "Ref. 4" and replaced with "Regulatory Guide 1.70."
74.	Editorial	Changed to eliminate gender-specific reference.
75.	Editorial	Changed to eliminate gender-specific reference.
76.	SRP-UDP format item	Deleted unnecessary callout for "(Ref. 1)."
77.	Integrated Impact No. 775	Replaced the AISC Specification with ANSI/AISC N690-1984 to reflect current PRB design criteria.
78.	SRP-UDP format item	Deleted unnecessary callout for "(Ref. 3)."
79.	Editorial	Changed "assures" to "ensures".
80.	Editorial	Changed "assure" to "ensure."
81.	Editorial	Changed "assure" to "ensure."
82.	Integrated Impact No. 777	Added information relating to the Staff's acceptance in the evolutionary FSERs an exemption to eliminate the OBE from seismic design requirements.
83.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.
84.	Editorial	Changed to eliminate gender-specific reference.

Item	Source	Description
85.	Editorial	Provided "SER" as an initialism for "safety evaluation report."
86.	Editorial	Changed "are" to "is" to provide number agreement.
87.	Editorial	Changed "assuring" to "ensuring."
88.	Editorial	Replaced "other than containment" with "described in this section."
89.	Editorial	Changed "assuring" to "ensuring."
90.	SRP-UDP format item	Added "such that they are" for clarity and readability.
91.	SRP-UDP format item	Added "6."
92.	Integrated Impact No. 772	Deleted reference to RGs 1.10, 1.15, and 1.55 to reflect their withdrawal.
93.	SRP-UDP format item	Added "7."
94.	SRP-UDP Format Item, Implement 10 CFR 52 Related Changes	To address design certification reviews a new paragraph was added to the end of the Evaluation Findings. This paragraph addresses design certification specific items including ITAAC, DAC, site interface requirements, and combined license action items.
95.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard sentence to address application of the SRP section to reviews of applications filed under 10 CFR Part 52, as well as Part 50.
96.	SRP-UDP Guidance	Added standard paragraph to indicate applicability of this section to reviews of future applications.
97.	Integrated Impact #1402	Specified ACI 349-1976 (S79) based upon endorsement in Regulatory Guide 1.142.
98.	Integrated Impact No. 775	Replaced the AISC Specification with the ANSI/AISC Specification to reflect current design criteria.
99.	Integrated Impact No. 768	Changed title of GDC 4 to reflect its current title.
100.	Integrated Impact No. 772	Deleted reference to RGs 1.10, 1.15 and 1.55 to reflect their withdrawal.
101.	Integrated Impact No. 772	Changed reference number to reflect withdrawal of RGs 1.10, 1.15, and 1.55.
102.	Integrated Impact No. 772	Changed reference number to reflect withdrawal of RGs 1.10, 1.15, and 1.55.
103.	Integrated Impact No. 772	Changed reference number to reflect withdrawal of RGs 1.10, 1.15, and 1.55.
104.	Integrated Impact No. 772	Changed reference number to reflect withdrawal of RGs 1.10, 1.15, and 1.55.

Item	Source	Description
105.	Integrated Impact No. 772	Changed reference number to reflect withdrawal of RGs 1.10, 1.15, and 1.55.
106.	SRP-UDP format item, Integrated Impact 1401	Added reference to ACI-318 Code, indicating the reference version as 1977, based upon endorsements in RGs 1.142 and 1.143.
107.	SRP-UDP format item	Deleted "INTERIM" from title.
108.	SRP-UDP format item	Deleted "interim" from text.
109.	SRP-UDP format item	Deleted reference to masonry walls at operating plants.
110.	SRP-UDP format item	Deleted reference to operating plants.
111.	SRP-UDP format item	Replaced "containment" with "combinations."
112.	SRP-UDP format item	Deleted reference to unreinforced masonry.
113.	SRP-UDP format item	Deleted reference to unreinforced masonry.
114.	Editorial	Added "the" for readability.
115.	SRP-UDP format item	Deleted Note (2), pertinent to unreinforced masonry.
116.	SRP-UDP format item	Deleted reference to seismic analysis of operating plants.
117.	SRP-UDP format item	Replaced "compared" with "compressed.
118.	SRP-UDP format item	Deleted "Licensees."
119.	SRP-UDP format item	Deleted criteria item (a), pertinent to licensees.
120.	SRP-UDP format item	Replaced item (b) with item (a).
121.	SRP-UDP format item	Replaced item (c) with item (b).
122.	SRP-UDP format item	Added "provided by the applicant" to specify originator of design report.
123.	Editorial	Changed to eliminate gender-specific reference.
124.	SRP-UDP format item	Added lead-in sentence to include Reference 1.1 in the text.
125.	SRP-UDP format item	Changed to reflect current SRB name and abbreviation.
126.	SRP-UDP format item	Changed to reflect current PRB name.
127.	SRP-UDP format item	Changed to reflect current SRB abbreviation.
128.	SRP-UDP format item	Added References 1.4 and 3.1.
129.	SRP-UDP format item	Added lead-in sentence to include Reference 3.2.
130.	SRP-UDP format item	Added References 3.3 and 3.4.

Item	Source	Description
131.	SRP-UDP format item	Added additional information regarding ASME Code.
132.	SRP-UDP format item	Provided a better description of Ref. 3.1.
133.	Integrated Impact No. 650	The latest revision of the ANSI N210 was issued in 1983. Its acceptability by the staff will determine when comparative study is completed.
134.	SRP-UDP format item	Added title of ANSI 210.
135.	SRP-UDP format item	Changed numbering system of references to conform with the text.
136.	SRP-UDP format item	Corrected author's name in REFERENCES.
137.	Integrated Impact No. 774	Added Appendix E, "Technical Position on Steel Embedments." The text of this appendix was taken from Appendix F of the ABWR FSER (NUREG-1503). A virtually identical appendix can be found in Appendix 3A of the System 80+ (NUREG-1462).
138.	Integrated Impact No. 775	Added Appendix F, "Staff Position and Technical Bases on the Use of Standard ANSI/AISC N690-1984 Nuclear Facilities: Steel-Related Structures." The text of this appendix was taken from Appendix G of the ABWR FSER (NUREG-1503). A virtually identical appendix can be found in Appendix 3B of the System 80+ Design, NUREG-1462.
139.	Integrated Impact No. 776	Added Appendix G, "TECHNICAL POSITION ON DYNAMIC LATERAL SOIL PRESSURES ON EARTH RETAINING WALLS AND EMBEDDED WALLS OF NUCLEAR POWER PLANT STRUCTURES." The text of this appendix was taken from Appendix H of the ABWR FSER (NUREG-1503).

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SRP Draft Section 3.8.4
Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
650	Some industry standards (ACI-318, ACI-349, and UBC) cited in SRP Section 3.8.4 have been revised. Others (ACI-531, 531R) have been replaced. In some cases, specifications cited in SRP Section 3.8.4 have been replaced by other standards (AISC by ANSI/AISC N690 and ANSI N210 by ANS 57.2). Some have partial acceptance by the staff, but the associated RGs endorse outdated issues (e.g., ACI-349). The standards cited in SRP Section 3.8.4 and the associated RGs need to be reviewed for their acceptability and consistency.	This Integrated Impact concerns outdated industry standards. No change was made to the SRP.
768	Title of GDC 4 has been changed	REFERENCES
769	SRP Section 3.8.4 does not reference specific issues of industry standards, implying that the latest edition endorsed by a regulatory guide is to be used. RGs endorse standards by date of issue. For example, RG 1.142, "Safety-Related Concrete Structures for Nuclear Power Plants (Other Than Reactor Vessels and Containments)" Rev. 1, October 1981, endorses ACI 349-76 and its 1979 supplement, except for Appendix B. Meanwhile, the ACI 349 Code has been revised and the latest revision, as indicated in the NUREG/CR 5973, was issued in 1990. The revisions of the ACI 349 Code may not be acceptable to the staff. Therefore, a critical review of the revised Codes is needed.	This Integrated Impact concerns outdated Regulatory Guide 1.142 and the ACI 349 Code. No change was made to SRP Section 3.8.4.
771	10 CFR 100 Appendix A, V(d)(4), requires that distant safety-related structures should be designed to withstand the effects of the SSE.	AREAS OF REVIEW, I.f
772	RGs 1.10, 1.15, and 1.55, all listed in SRP Section 3.8.4, have been withdrawn.	ACCEPTANCE CRITERIA, II.2; REFERENCES
773	The SRP has been revised to refer to the new leak-before-break (LBB) load definitions in SRP Section 3.6.3 (to be developed).	AREAS OF REVIEW, Review Interfaces 5
774	RG 1.142 provides staff positions related to the use of ACI 349-76, "Code Requirements for Nuclear Safety-Related Concrete Structures." RG 1.142 excludes Appendix B, "Steel Embedments," of ACI 349-76 in its consideration. Staff positions on steel embedments have been incorporated in the SRP Section 3.8.4 as Appendix E.	AREAS OF REVIEW, I.4; ACCEPTANCE CRITERIA, II.2 and II.4.a; Appendix E.

SRP Draft Section 3.8.4

Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
775	In FSERs for the System 80+ and ABWR, the staff found the use of ANSI/AISC N690-1984, "Nuclear Facilities: Steel Safety-Related Structures," to be acceptable (with exceptions). The staff exceptions to ANSI/AISC N690-1984 have been incorporated in the SRP Section 3.8.4 as Appendix F.	AREAS OF REVIEW, I.4; ACCEPTANCE CRITERIA, 3.c(i) and 3.b; REFERENCES; Appendix F.
776	The staff positions on dynamic lateral soil pressures on earth retaining walls and embedded walls have been incorporated in the SRP Section 3.8.4 as Appendix G.	AREAS OF REVIEW, I.4 and I.4.i; ACCEPTANCE CRITERIA, II.3.a and II.4.g; Appendix G.
777	Loads and load combination equations associated with the operating basis earthquake (OBE) have been eliminated to reflect the provisions of SECY 93-087.	REVIEW PROCEDURES
1244	Revise the SRP to incorporate the new and revised requirements from proposed rulemaking 59 FR 52255.	No changes to SRP at this time.
1293	Revise the Acceptance Criteria, Review Procedures, and Evaluation Findings as necessary to incorporate the guidance of the proposed draft Regulatory Guide EM-805-5.	No changes to SRP at this time.
1401	Consider updating the citation of ACI 318 to cite the 1977 version.	REFERENCES
1402	Consider updating the citation of ACI 349 to cite the 1976 (S79) version.	REFERENCES
1403	Standard AISC N690-1969 has been determined to be the version applicable to the SRP citation. Consider updating the citation of AISC to cite the 1969 version.	Citations revised under II No. 775.